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Amaresh Chakrabarti *Editor*

Research into Design for a Connected World

Proceedings of ICoRD 2019 Volume 2

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Editor

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Preface

Design is ubiquitous; it pervades all spheres of life and has been around ever since life has been engaged in purposefully changing the world around it. While some designs have transcended time, most designs are in a perpetual process of being evolved. Research into design and the emergence of a research community in this area have been relatively new. Its development has been influenced by the multiple facets of design (human, artefact, process, organisation, ecology, micro- and macro-economy by which design is shaped and which it shapes in turn) and the associated diversification of the community depending on the facets of focus or that of their applications. Design is complex, balancing the needs of multiple stakeholders and requiring a multitude of areas of knowledge to be utilised, with resources spread across space and time.

The collection of papers in these two book volumes constitutes the Proceedings of the Seventh International Conference on Research into Design (ICoRD'19) held at Indian Institute of Science, Bangalore, India, during 9–11 January 2019. ICoRD'19 is the seventh in a series of biennial conferences held in India to bring together the international community from diverse areas of design practice, teaching and research. The goals are to share cutting-edge research about design among its stakeholders; aid the ongoing process of developing a collective vision through emerging research challenges and questions; and provide a platform for interaction, collaboration and development of the community in order for it to address the global and local challenges by forming and realising the collective vision. The conference is intended for all stakeholders of design and, in particular, for its practitioners, researchers, teachers and students.

Four hundred and five abstracts were submitted to ICoRD'19, from which 327 were accepted for full paper submission. Two hundred and fourteen full papers were submitted, which were reviewed by experts from the ICoRD'19 International Programme Committee comprising 217 members from over 145 institutions or organisations from 32 countries spanning five continents. Finally, 169 full papers, authored by 352 researchers (352 unique authors, actually 451 author entries in 169 papers) from 106 institutions and organisations from 16 countries spanning 5 continents, were selected for presentation at the conference and for publication as chapters in this book. ICoRD has steadily grown over the last six editions, from a humble beginning in 2006 with 30 papers and 60 participants, through 75 papers and 100 participants in ICoRD'09, 100 papers and 150 participants in ICoRD'11, 114 papers and 170 participants in ICoRD'13, 118 papers and 200 participants in ICoRD'15, and 178 papers and 230 participants in ICoRD'17.

ICoRD'19 had 134 podium papers and 36 papers with brief podium presentations followed by poster display and discussion. It had keynotes from prominent researchers and practitioners from around the world such as John Gero from George Mason University, USA; Ravi Poovaiah from Indian Institute of Technology Mumbai, India; Farrokh Mistree from University of Oklahoma, USA; Aloknath De from Samsung, India; Yukari Nagai from Japan Advanced Institute of Science and Technology, Japan; and Janet McDonnell from University College of the Arts London, UK. It had a panel discussion on "Writing Journal Papers" and three workshops on Ph.D. Students Symposium, Structure Sharing, and Publishing Papers. Since 2015, ICoRD has initiated ICON^3 Awards (acronym for **I**CoRD **O**utstanding **C**ontribution to desig**N** scie**N**ce and educatio**N**) to be given to two outstanding contributors to design education and research at each ICoRD. Professor Sudhakar Nadkarni from Welingkar Institute of Management, India, and Professor John Gero from George Mason University, USA, were selected as the ICON^3 awardees for 2015, for their outstanding contributions to design education and design research, respectively. Professors Amit Ray from Shiv Nadar University, India, and Cees de Bont from Hong Kong Polytechnic University, Hong Kong, had been selected as the ICON^3 awardees for 2017. For ICoRD'19, the ICON awardees are Professor Imre Horvath from Delft University of Technology, the Netherlands, and Professor T. S. Mruthyunjaya from Indian Institute of Science, Bangalore, India.

The chapters in the two book volumes together cover all three major areas of products and processes: functionality, form and human factors. The spectrum of topics ranges from those focusing on early stages such as creativity and synthesis, through those that are primarily considered in later stages of the product life cycle, such as safety, reliability or manufacturability, to those that are relevant across the whole product life cycle, such as collaboration, communication, design management, knowledge management, cost, environment and product life cycle management. Issues of delivery of research into design, in terms of its two major arms: design education and practice, are both highlighted in the chapters of the book volumes. Foundational topics such as the nature of design theory and research methodology are also major areas of focus. It is particularly encouraging to see in the chapters the variety of areas of application of research into design—aerospace, health care, automotive and so on.

The theme of ICoRD'19 has been "Design for a Connected World". While design traditionally focused on the development of products that worked on their own, the emerging trend is to have products with a smart layer, which makes them context-aware and responsive, both individually and collectively, through collaboration with other physical and digital objects with which these are connected. The key is connectivity: how do products and their development change in a connected world? ICoRD'19 is hosted in Bangalore, which is the "silicon plateau" of the world, with the second fastest growing community of start-ups, many of which are exploring emerging technologies such as IOT, IIOT, digital twins, sensor networks, I4.0 and so on to design new products, systems and services. It is only appropriate that the theme for ICoRD'19 aligns with this ambiance.

This volume, "Research into Design for a Connected World—Proceedings of ICoRD 2019 Volume 2", focuses on the topics of design ideation, creativity and synthesis, design, knowledge, innovation and product life cycle management, entrepreneurship, design aesthetics, semiotics and semantics, human factors in design including design of/for user interfaces, user experience and human–computer interaction, design collaboration and communication, and design training and education.

On behalf of the Steering Committee, Advisory Committee, Organising Committee and Co-Chairs, we thank all the authors, delegates, institutions and organisations that participated in the conference. We also thank the members of the International Programme Committee for their support in reviewing the papers for ICoRD'19, which is essential for maintaining the quality of the conference, and for their support in putting this book together.

We are thankful to the Design Society and Design Research Society for their kind endorsement of ICoRD'19. We thank Indian Institute of Science (IISc), Bangalore, and its Centre for Product Design and Manufacturing, for their support of this event. We also wish to place on record and acknowledge the enormous support provided by Ms. Kumari M. C., Mr. Ranjan B. S. C., Mr. Apoorv Bhatt, Mr. Ishaan Kaushal, Mr. Kiran Ghadge, Mr. Anubhab Majumdar, Mr. Paridhi, Mr. Dhiraj Kumar, Mr. Praveen Uchil and Ms. Nishath Salma of IISc in managing the review process and in preparation of the conference programme and this book and the conference as a whole. We also thank the large and dedicated group of student volunteers of IISc Bangalore in the organisation of the conference. Finally, we thank Springer, especially its Editor Ms. Swati Meherishi and its editorial support team, for their wonderful support.

Bangalore, India Amaresh Chakrabarti

About the Conference

Design is ubiquitous; it pervades all spheres of life and has been around as long as life has taken up the task of purposefully changing the world around it. Research into design and the emergence of a research community in this area have been relatively new. Its development has been influenced by the multiple facets of design (human, artefact, process, organisation, the micro- and macro-economy and the ecology by which design is shaped) and the associated diversification of the community depending on the facets of focus or that of their applications. Design is complex, balancing the needs of multiple stakeholders and requiring a multitude of areas of knowledge to be utilised, with resources spread across space and time.

ICoRD'19 is the seventh in a series of conferences intended to be held every two years in India to bring together the international community from diverse areas of design practice, education and research. It aims to showcase cutting-edge research about design to the stakeholders; aid the ongoing process of developing and extending the collective vision through emerging research challenges and questions; and provide a platform for interaction, collaboration and development of the community in order for it to take up the challenges to realise the vision. The conference is intended for all stakeholders of design and, in particular, for its practitioners, researchers, pupils and educators.

The collection of papers in these two book volumes constitutes the Proceedings of the Seventh International Conference on Research into Design (ICoRD'19) held at Indian Institute of Science, Bangalore, India, during 9–11 January 2019. ICoRD'19 is the seventh in a series of biennial conferences held in India to bring together the international community from diverse areas of design practice, teaching and research. The goals are to share cutting-edge research about design among its stakeholders; aid the ongoing process of developing a collective vision through emerging research challenges and questions; and provide a platform for interaction, collaboration and development of the community in order for it to address the global and local challenges by forming and realising the collective vision. The conference is intended for all stakeholders of design and, in particular, for its practitioners, researchers, teachers and students.

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The conference contained:

- Invited/keynote presentations from eminent international experts and practitioners;
- Panel discussion and presentations of refereed papers as podium and poster presentations;
- Presentation of ICoNNN awards and keynotes;
- Networking sessions for young researchers;
- A Ph.D. students symposium and workshops on dedicated topics.

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About the Editor

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Part I
Design Ideation, Synthesis and Creativity

Chapter 1
Standardization of Terminologies for Physical Models in Design Process

T. N. Subramanya and B. K. Chakravarthy

Abstract This paper proposes a generalized approach to classify physical models, considering the existing classifications by researchers in the past. The terms like models, mock-ups, prototypes, etc. are used to convey different meanings at each stage of the design process which lacks clarity. Although many high-level classifications of the physical models exist, the information available is very little and conflicting. A detailed guideline-based approach across a design process is required which is not rigid but flexible without infringing on the importance of language in creativity. The first part of the paper describes the role of physical models in design. The second part explains existing classifications and the underlying factors for classification and lists a set of guidelines to generalize the classification and standardize the terminologies. The third part of the paper proposes a set of terminologies to classify the physical models across different phases of the design process.

1.1 Introduction

Designing is a complex activity, and the outcome involves manipulation of the designer's internal representations which is key to innovation. However, the inadequate internal representations give rise to the need for external representations of the idea. A designer should have the ability to represent an object/idea in some form in a space to act as a stable display for him to manipulate easily so that he can creatively iterate to arrive at a solution [1]. In the early phase of the design process, designers use various external representations in capturing and developing initial fragile ideas, and physical model making is an established method of external representation. Physical models are of various types ranging from quick and dirty

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mock-ups to accurate to scale prototypes for relection, evaluation and communication.

Physical models have been instrumental over the centuries in producing innovative representations and forms to connect better with the expectations of different stakeholders [2, 3]. Designers have been using physical models to ideate, visualize and evaluate the ideas and concepts across all phases of the design process. Prior research promotes the use of physical prototyping as an effective tool to generate and develop new ideas, as the physical prototypes supplement and improve designer's incorrect mental models and enhance creativity and functionality of the ideas [4]. Also countering this view, other researchers warn designers to think before using physical prototyping as it can introduce fixation due to various factors like time and cost or 'functional' and 'mental set' fixedness [4].

Many researchers in the past have advocated using physical models in idea generation phase, where the ideas are still fluidic in nature which can be improvised easily as physical models help the designers to externalize the thought process for better visualization and reworking. Isa and Liem [5] describes model making (mock-ups) as a way for designers to explore form, composition and functionality from idea to detail design. Compared to sketches and virtual prototypes, by using the physical models, the designer can get clear insights about form, function and construction. Referring to three-dimensional sketching (model making), Rowena Reed opines that the 3D forms reflect the direct visual experience of the thing, how forms and spaces and movements 'speak' to one another [6].

Primarily, the terminologies like 'physical models' or 'prototypes' are borrowed from other fields like mechanical or manufacturing domains and are not relevant to all phases of the design process. Researchers have classified physical prototypes based on factors like the design process, materials used, purpose, dimensions, stages, fidelity, etc. So far, no standard set of terminologies are followed in classifying the physical models. After reviewing the literature from many researchers in the past, one can come to the conclusion that the terminologies used in defining the physical models at various stages of design process are not standardized and the information available is very little and conflicting.

1.1.1 Comparing Sketching and Physical Models

Till recently with respect to external representation, studies were conducted mainly on sketching or absence of sketching to understand the characteristics of imagery [7]. Physical prototypes are less studied compared to sketching which is an object frozen in time and form and a fluid structure changing its appearance and meaning. External representations, especially the physical models, allow the designer to pick up the inherent design flaw early and rapidly change it in the mental simulations. Affordances of physical models may better facilitate the mental simulations compared to sketching or no external representations.

Sketches support visual perception well, but do not support other sense modalities (haptic, gustatory, auditory and olfactory) which the physical models support suggesting that the physical models will be superior to sketches in perception in some but not all modalities. Also, the cognitive support offered by physical models reduces mental simulations more than sketches [1]. Mental simulations are of two types: the first one supports the functional and mechanical simulations, and the second one supports the end-user behaviour or the usability; both of them are well supported by the physical models compared to sketches. However, if uncertainty is considered as the primary factor and key driver in new inventions in design arising out of inadequate internal representations, sketches provide more uncertainty because they are purposefully ambiguous and allow for creative re-interpretations. Since the mind constructs an object internally in three-dimension, externalizing it in three-dimension would produce more accurate representation and also it corrects the incomplete or incorrect mental model based on which the object is constructed (Fig. 1.1).

This leads to a situation where a combination of sketching and prototyping being used to maximize the advantages of both representations as multiple forms of representations leads to better understanding, acquisition and memorization of the concept [8].

1.1.2 *Comparing Physical Prototypes with Virtual Modelling*

The influence of computers and digital devices has entered in every part of our life, and today designers use it even in the ideation phase. Although they help in other aspects of professional work for a designer like communication and collaboration in the design process, in its contribution to ideation, it has introduced rigid constraints

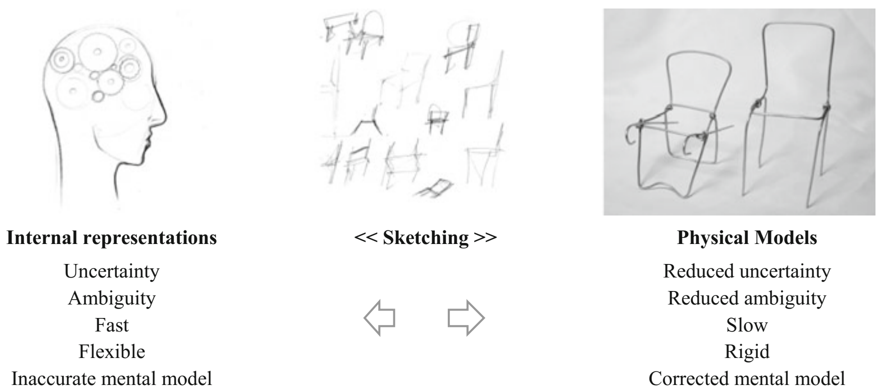

Fig. 1.1 Internal representations, sketching and physical models [22]

for the designer [9]. There is a dependency on the tool, and the designer is confined within the limits of the digital environment and also within the designer's skill level of the tool.

The physical forms inhabit the real space of the viewer compared to the imaginary space of the virtual models. Models constructed manually benefit from spontaneous juxtapositions and serendipitous interactions with light and gravity. Converting these models into the digital realm allows the computer to take over in areas that it does best: geometric transformation, rigorous analysis, elaboration and coordination of details and complexity [10].

1.2 Existing Classifications of Physical Models

Hallgrimsson defines 'prototyping' as a design method that uses physical prototypes to study and test the new concept with respect to form, function and usability. He further defines 'model making' as a step-by-step instruction to make a 'prototype' [11]. Other researchers like Kojima define physical model making as the next logical step in thinking process for every design idea [12]. Kelly strongly recommends in using it in design process where ideas are bettered using materials and fabrication techniques implying that each designer is served by a model making approach while translating an idea into reality [13]. Isa and Liem [14] describes soft model as a rough model representing the idea for assessing overall size, shape and proportion of the proposed idea.

As per Ulrich and Eppinger [15], a prototype is an approximation of the proposed product idea in one or more dimensions. The dimensions can be:

A. **Physical or analytical**: Physical prototype is an object which looks similar to the final product whereas analytical models are intangible like mathematical model.
B. **Focussed or comprehensive**: A focussed model can be a part or parts of the concept, and a comprehensive model has a holistic approach.

There are many classifications of mock-ups/models/prototypes by different researchers which are as follows (Table 1.1).

All kinds of easy to deform materials can be used to construct which is easy to shape and manipulate for fast evaluation of form and function, also depending on the feedback, the soft model can easily be changed. The designer adopts a more reflective way of shaping and moulding the model by hand continuously analysing it. Soft models are instrumental for designers in translating their ideas into reality and give next clear directions for the creative stages of the design process. It is easy to make changes to the soft model in the early stages, and the modification cost goes higher exponentially towards the final stages of the process. Hard models are technically non-functional but close replicas of final product, and it takes time to make these models. Presentation models are constructed through CAD data and

Table 1.1 Classification of physical prototypes by various researchers

Author(s)	Classification of mock-ups/ models/prototypes	Observation
Kojima [12]	• Image models • Rough mock-up models • Presentation models • Prototype models	Sketching included along with physical models
Mascitelli [24]	• Initial rough models • Refined models • Formative prototypes • Refined prototypes	4-level classification with models and prototypes as basic divisions
Ullman [25]	• Proof of concept • Proof of product • Proof of process • Proof of production	Classifies models based on functionality
Ulrich and Eppinger [15]	• Soft model • Hard model • Control model • Prototype	Simplified version based on material and purpose
Isa and Liem [14]	• Soft model • Hard model • Presentation model • Prototype	A combination based on the previous researchers' classification

control drawings which are fully detailed. The prototype is divided into formative prototype for user evaluation or summative prototype which is fully finished before production.

1.2.1 Limitations of Physicals Models

Many researchers believe that the designer should be careful in resorting to model making as a lot of time effort and resource are involved which in the course of time may influence the decision and design directions. This limitation is known as design fixation, but this view is countered by the observation that the fixation is a general phenomenon and is induced by many other factors which is present in all other types of representations [1, 16].

According to the studies conducted so far, there are conflicting results as it was found that there is high degree of fixation as per Christensen and Schunn [1] and no fixation as per Viswanathan and Julie [4]. Others emphasize that choosing the right type of physical prototype plays a very important role in generating high quality of ideas and suggests that in idea generation stage, less detailed high-level physical prototypes are more effective [17, 18]. This also indicates that choosing the right kind of prototype and building material also influences the fixation.

In the context under consideration, design fixation can occur due to the following factors [4]:

- Time
- Prototype building process
- Constraints present in building materials
- Sunk cost
- Anticipated cost.

1.2.2 Guidelines for Classification

Observations of the different classifications indicate that the current classifications are at high level and do not cover all aspects of the industrial design process. A set of following guidelines emerged from the literature study, discussions with academicians, students and industry experts. These guidelines were used as a backdrop in exploring standardizations for physical models.

1. **The designer's workflow should be taken into account considering all forms of external representations**: A designer works by seamlessly moving between different forms of external representations especially between sketching and physical models. So far only Kojima includes image models, and rest of the classifications do not include the sketches. While standardizing the terminologies, both sketching and physical models should be taken into account.
2. **The iterations and refined versions of the models in the design process should be clearly indicated**: Iteration is key to evolution of design from a hazy idea to a full-scale prototype, and the iteration factor should be indicated in the terminology standardization.
3. **Ambiguity in terminologies should be avoided**: The terminologies currently used are not relevant to all phases of design process, especially in the ideation phase.
4. **Purpose and approximation should be evident**: A physical model is made for different purposes to analyse form, function and proportion. The degree to which the final product is to be approximated should be included where a certain set of attributes are considered while building the model.

1.2.3 Terminologies and Definitions

Understanding the definitions of various terms used for physical models forms the first step in standardizing the terminologies which are as follows:

Mock-up: This is a scaled or full-size model of something large that has not yet been built, showing how it will look or operate. Ulrich and Eppinger define mock-up as an initial and rough representation of design intent where the aim of the designer is to show something rather quickly than accurately [15]. A 'quick and dirty mock-up' takes less time in doing it and costs less.
Model: Models are three-dimensional representations of the proposed design usually in a scaled down version where the scale of the model is arbitrary [15].
Prototype: These are full-scale working models. According to Ulrich and Eppinger, it is an approximation of the product in one or more dimensions of interest, and Hallgrimsson defines the prototype as the three-dimensional representation of the product, service or system [11, 15].
Fidelity: According to the Oxford dictionary, it is the degree of exactness with which something is copied or reproduced. 'Low', 'medium' and 'high' are the attributes used indicating the level of approximation.
Idea: This is the most embryonic form of a new product or service. It often consists of a high-level view of the solution envisioned for the problem identified by the opportunity [19].
Concept: It has a well-defined form, including both a written and visual description, that includes its primary features and customer benefits combined with a broad understanding of the technology needed [19].

From the above information, it is evident that the term 'mock-up' is appropriate at the early stage of the design process, 'idea exploration phase', where the aim is to show something rather quickly than accurately and the designer is still working on the hazy and uncertain ideas to eventually evolve some of them into concepts which can be pursued further.

The level of approximation of a model across the design process can be indicated by low-, medium- and high-fidelity models, and for the later stages of the design process, where functional and user testing and acceptance is tested, the terms 'model' and/or 'prototype' are more appropriate.

1.3 Standardization of Terminologies

Based on the guidelines derived from the previous classifications and the definitions, the following categories are proposed. The models are broadly divided into three stages as follows:

- Stimulation mock-ups
- Presentation models
- Simulation models (Table 1.2).

Table 1.2 Proposed classification of physical prototypes

Physical/image models in design process		
Stage 1—stimulation mock-ups	**Stage 2—presentation models**	**Stage 3—simulation models**
Stage 1A—low-fidelity exploration mock-ups		***Stage 3A—formative prototype***
Image mock-ups		Comprehensive
Doodles		Focussed
Thumbnails		
Physical mock-ups		
Exploration form mock-ups		
Exploration function mock-ups		
Stage 1B—medium-fidelity conceptual mock-ups		**Stage 36—summative prototype**
Physical mock-ups		Comprehensive
Conceptual form mock-ups		
Conceptual function mock-ups		
Image mock-ups		
Concept sketches		
Closed group (within team)		**Open group**

1.3.1 Stimulation Mock-Ups

Stimulation mock-ups mainly deal with the ideation process where the mock-ups are made to reflect on the journey from an idea to a concept within designer or the team. As the name suggests, in this stage the mock-ups, both image and physical, are made to represent the vague internal representation to an external representation to evolve and nurture the fragile idea. A designer starts with initial sketches as doodles which evolve into thumbnails. At this stage, the designer can switch to 3D models either to have a feel of the form or function or both. Once the ideas are represented in 3D models, the designer further refines some or all of the mock-ups which are called conceptual mock-ups. Once the concept is clear in the 3D mock-ups, the designer can switch back to sketching where different ideas/concepts can be combined to make a new concept or a concept can further be refined during sketching. The mock-ups that are made in this stage will take very less time, and the materials used will be of less cost to avoid design fixation.

A. **Low-fidelity exploration mock-ups**: In this stage, as the name suggests, the mock-ups are made quickly with any available and easily deformable materials to represent an idea.

   Image mock-ups—Doodles and thumbnails: The design activity starts with a doodle and slowly evolves into a thumbnail. David Bramston in his book 'Basics of product design—Idea search' defines doodle as less intentional and more abstract, and it is a result of subconscious mind, and it is not produced with much concentration, and due to the lack of clarity and presence ambiguity, the scribbles and marks of a doodle carefully placed in context. The thumbnails offer the first glimpse of an idea visually represented which aims to capture the essence of a concept [20] (Figs. 1.2 and 1.3).

At this stage, the doodles and thumbnails are called image mock-ups and the designer, after producing as many image mock-ups as possible moves to the next stage to make the 3D models.

Physical mock-ups—Form and function mock-ups: At this stage, the designer continues the ideation process by making three-dimensional models using easily deformable materials like paper, foam board, polystyrene foam, clay, wood, etc. Here, the intention may be to answer the designer's questions concerning overall form and function as Hallgrimsson [11] calls these as 'looks like' and 'works like' prototypes. When the mock-ups are made with respect to form, these are called 'exploration form mock-ups', and for function, it is called 'exploration function mock-ups'. A mock-up can also be made with respect to form and function, and in this case, it is called 'exploration comprehensive mock-up' or 'exploration form and function mock-ups'. While making the models from thumbnail sketches, the designer may fuse a few ideas and also develop a new idea entirely. The ideation process is still continuing at this stage (Figs. 1.4 and 1.5).

B. **Medium-fidelity conceptual mock-ups:** At this stage, the designer starts the iteration process and refines a few of the mock-ups from the previous stage or may come up with an entirely new mock-up based on the previous experience. Also, new concepts may emerge by combining two or more ideas.

Fig. 1.2 Doodle [23]

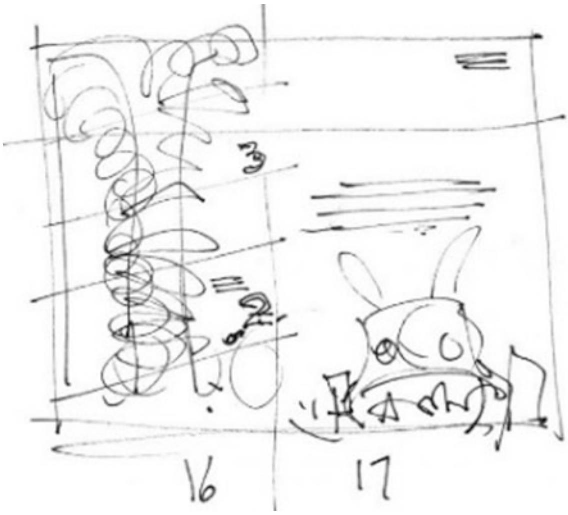

Fig. 1.3 Thumbnail sketches of chairs [23]

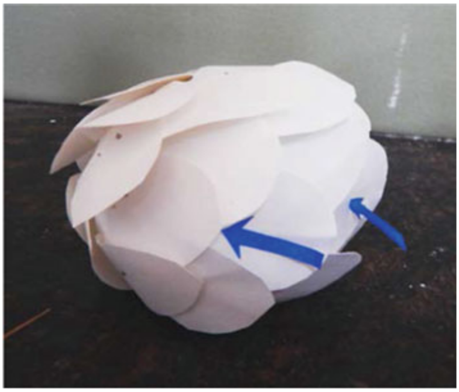

Fig. 1.4 Exploration form mock-up [22]

Fig. 1.5 Exploration function mock-up [22]

Fig. 1.6 Conceptual form mock-up [22]

Physical mock-ups—Form, function and comprehensive models: As the design evolves, a few of the mock-ups can be refined after several internal feedback loops. Although this step is separated from the previous step, in reality both the steps can be indistinguishable from each other. Also, many concepts can be fused to get a new refined concept or an entirely new concept can be evolved inspired by the mock-ups made in the previous step. The mock-ups made at this stage are called 'conceptual form mock-ups', 'conceptual function mock-ups' or 'conceptual form-function mock-ups' (Figs. 1.6, 1.7 and 1.8).

Image mock-ups—Conceptual sketches: Here, the designer continues the ideation process by getting back to the drawing table to sketch the final idea/s. With good knowledge about the form and intended function, the ideas are more distinct and functional. Refined image models along with refined physical

Fig. 1.7 Conceptual function mock-up [22]

Fig. 1.8 Conceptual sketches [22]

models can be used to evaluate and finalize the concept to decide the next directions.

1.3.2 Presentation Models

These models can be either image, virtual or physical, used to present the product concept to either stakeholders for sign-off purpose or users for marketing purpose. The presentation models are prepared after stimulation mock-ups to get a sign-off from stakeholders and/or towards the end for marketing and user feedback.

1.3.3 Simulation Models

Simulation models deal with testing the product concept for functionality and/or usability. The prototypes in this stage range from scaled to full-scale model of the proposed concept. The prototypes can be formative where the product is tested to get feedback to refine or summative where the prototype is being tested before mass production. The models made at this stage will take time, and material cost can be from moderate to high [14]. The prototypes can also be made by using the 3D printing technology where the models are virtually made and then printed using a 3D printer.

Formative prototypes—Functionality and/or Usability: Formative prototypes are made in either full scale or scaled version to simulate the product working/ features so that it can be evaluated for the same. Formative prototypes can be focussed or comprehensive and also can be used to evaluate either functionality or usability. Formative prototypes still give scope for accommodating the feedback from stakeholders and users.

Summative prototypes—Functionality and/or Usability: Summative prototypes are made towards the end of the design activity to full scale with actual materials which go into making the product. Like formative prototypes, this is made to evaluate functionality or usability. The feedback from formative prototypes is addressed in the summative prototypes, and at this stage, the prototype is aimed at manufacturing and less changes are anticipated and accommodated.

1.4 Models Across Design Process

Various types of models are made during the different stages of design process to reflect upon the design. Models made at each stage are meant to answer a particular type of question in the designer's mind. Although the proposed set of terminologies are mapped across the double-diamond design process by Design Council, UK [21], the same set can be mapped on any other design process (Fig. 1.9).

The idea generation phase in the 'define' stage is divided into two subdivisions to accommodate the 'low-fidelity exploration mock-ups' which are made during

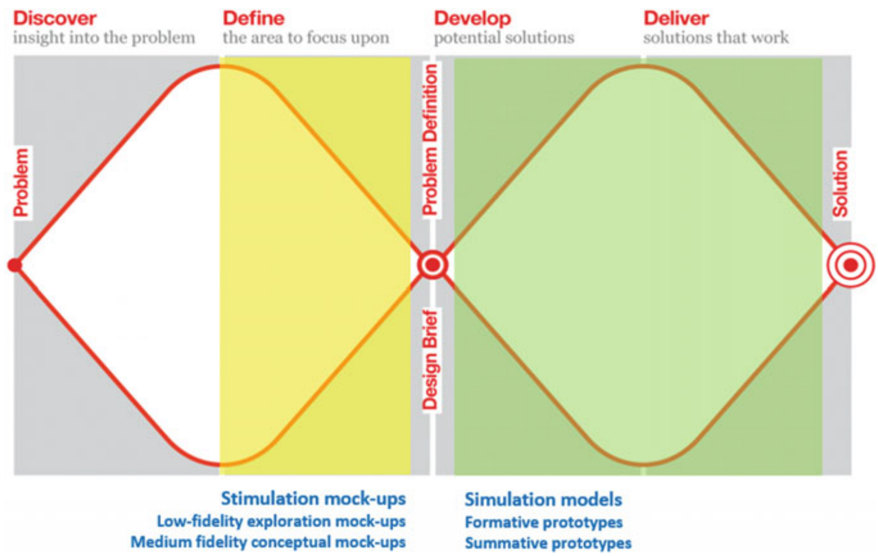

Fig. 1.9 Proposed terminologies double-diamond design process [21]

idea generation and ‘medium-fidelity conceptual mock-ups’ to arrive at concept stages by refining the mock-ups from the previous step. The designer/team while arriving at this stage would have generated several ideas and after careful self-evaluation would have refined/combined ideas into concepts. Concept finalization occurs at this stage as per the procedure of concept validation and the detailing of the concept begins. At this stage of the design process, the project sign-off phase requires the presentation models.

While detailing the concept in the ‘develop’ phase, the designer or the team to reflect on the design development builds formative prototypes which are used for validating with the users. The scale and the material of the model are decided by the purpose and availability of time, cost and effort. The formative prototypes are refined based on the feedback from peers, users and stakeholders until it is finalized. A summative prototype is built as the final prototype along with other deliverables for manufacturing the product which marks the completion of the first round of the project. During ‘develop’ and ‘deliver’ phase, the strength of the virtual models which are geometric transformation, rigorous analysis, elaboration and coordination of details and complexity can be made use. Further, current 3D printing technology can be used to build part or whole prototype.

The proposed set of terminologies at different stages of the design process compared to recent classification by Isa and Liem [14] are as follows (Tables 1.3 and 1.4).

Further discussions with academicians, industry experts and students gave few more options which are regularly used in the design activity such as quick and dirty mock-ups, creating exploration mock-ups, working rigs, working prototypes, full-scale mock-ups, montage, etc., and these can be overlapped with the proposed solution.

1.5 Discussion

The study highlights the importance of using physical models at all stages of the design process and also compares it with other representations. The proposed generalized standardization is independent of the design process and could be mapped across different design processes. This brings in clarity and precise understanding which helps the designer to make use of the unique strengths and advantages of physical models. A standardized set helps in communication in both reflecting upon the idea/product and communicating within or outside the team. Also compared to the classifications from the prior research which is at a high level, this paper attempts to go a detailed level classification.

The paper addresses the context of ‘new product development’ in industrial design and takes specifically the double-diamond design process as it followed and accepted by the industry in general and also takes into account the present-day scenario of synergy of other disciplines coming together with industrial design.

Table 1.3 Comparison of proposed terminologies with the classification by Isa and Liem [14]

Double-diamond design process	Isa and Liem [14]		Proposed terminologies		
			Level 1	Level 2 (optional)	Level 3
Discover					Final terminologies
Define					
Generation of initial ideas for new product or service or both (prototyping/mock-ups)	Soft models	Stimulation mock-ups	Low-fidelity exploration mock-ups OR low-fidelity idea mock-ups	Image mock-ups	Doodles
					Thumbnails
				Physical mock-ups	Exploration form mock-ups
					Exploration function mock-ups
	Hard models		Medium-fidelity conceptual mock-ups	Physical mock-ups	Conceptual form mock-ups
					Conceptual function mock-ups
				Image mock-ups	Concept sketches
Project sign-off (conceptual stage)	Presentation models		Presentation models (image/physical/virtual)		
Develop					
Development methods (working prototypes are developed)	Prototypes	Simulation models	Formative prototypes	Focussed/ comprehensive	Formative prototypes
Testing					
Deliver					
Final testing, approval and launch			Summative prototypes	Full-scale mock-up	Summative prototypes
Targets, evaluation and feedback loops					

Table 1.4 Accommodating alternate terminologies

Double-diamond design process		Proposed terminologies			Alternate terminologies
		Level 1	Level 2 (optional)	Level 3	
Discover				Final terminologies	
Define					
Generation of initial ideas for new product or service or both (prototyping/mock-ups)	Stimulation mark-ups	Low-fidelity exploration mock-ups OR low-fidelity idea mock-ups	Image mock-ups	Doodles	Scribbles
				Thumbnails	Montage
			Physical mock-ups	Exploration form mock-ups	Quick arid dirty mock-ups
				Exploration function mock-ups	Working rig
		Medium-fidelity conceptual mock-ups	Physical mock-ups	Conceptual form mock-ups	3D sketching
				Conceptual function mock-ups	
			Image mock-ups	Concept sketches	
Project sign-off (conceptual stage)		Presentation models (image/physical/virtual)			
Develop					
Development methods (working prototypes are developed)	Simulation models	Formative prototypes	Focussed/ comprehensive	Formative prototypes	Working prototype
Testing					
Deliver					
Final testing, approval and launch		Summative prototypes	Full-scale mock-up	Summative prototypes	Full-scale model
Targets, evaluation and feedback loops					

With sufficient knowledge and care, the physical models can be used to produce innovative yet functional ideas.

The scope of this work is limited to sketching and physical models and does not consider other representations like digital prototyping and 3D printing which could be included as the next step.

1.6 Conclusion

Handmade mock-ups involve more sense modalities which are body-centric, personal, tacit and tactile along with sketching. This allows for multidimensional expression giving clear directions for the next creative stages of the design process. Having the standardized set of terminologies brings clarity to the design activities and makes use of the physical prototypes at appropriate stages. A guideline-based approach of classification brings flexibility and does not infringe on the role of language in creativity. Since the set is not rigid, new terminologies can be accommodated as alternate terminologies by using the guidelines. A detailed set of terminologies helps the designer to not only understand the process but also in planning. The terminologies define the stages and level of approximation and suggest materials that should be used in making the physical model.

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Chapter 2
Perceiving Design Processes as Embodied Experience

Mia A. Tedjosaputro and Yi-Teng Shih

Abstract Designers in action deal with numerous information flows. In this paper, design processes are examined with an alternative view of embodied cognition. The feedback loops across mind, body, and environment are investigated using this lens. Aiming to understand how the interplay of internal and external processes is constructed, verbal data was collected through a think-aloud experiment with 12 novice designers who contributed to 24 forty-five-minute design sessions with three design environments. Comparisons between interplay in sketching and mental imagery sessions are presented. It is concluded that it is possible to extend the view of designing by elaborating mind, body, and design environment into the cognition mix. The notions such as cognitive self-stimulation, design affordances, design effectivities, and designers as self-structures possibly expand the possibilities to understand the role of designing and design tools.

2.1 Introduction

Although traditionally designing has been studied in line with standard cognitive science; this paper takes an alternative view of embodied cognition. This viewpoint offers the explanation that cognition involves complex intermingling between mind, body, and environment. It is noted, however, that within the contrived experimental setting, the focus in this paper is interactivity between mind and body with limited environmental propositions. The aim of the paper is to attempt to demystify the interplay of internal and external processes in two different design conditions: sketching (with unlimited access to externalizations) and mental imagery (with staged access to externalizations) environments.

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2.2 Relevant Literature

2.2.1 Designer and the Environment

Ways in which designers interact with design environments have been posited in different lights. Gero and Kannengiesser posited the recursive process of interactions and introduced three worlds [1]. An external world is composed of representations outside the designer. The interpreted world is the world that is built up inside the designer. The expected world is the world the imagined actions of the designer or design agent will produce. Every change in one world effects changes in the others. By observing and interpreting the results of actions, designers decide new actions to be executed (ibid.).

Another notion was elicited in relation to the designer's conception of the design world over time. Designers have multiple sources of information to develop a design world [2]: the external world of object and observations, external sources of encoded information (such as books, Web sites, or drawings), and the internal recollection of the previous experience and learning. Through these sources, designers learnt and mentally encoded a rich structure of information.

Beyond discussions in designing, a basic principle of distributed representations was illustrated by Zhang and Norman [3]. The representational system of distributed cognitive tasks can be considered as a set of internal (propositions, productions, schemas, mental images, or other forms) and external (physical symbols or external rules embedded in physical configurations) representations. Respective representational spaces together form a distributed representational space, which is the representation of an abstract task space.

It is noted that there is a kind of causal feedback loop attributed to design processes, between different kinds of internal and external properties of designers. The designing mind constantly interacts with the external world, external representations, and external sources while on action. These feeding actions are the point of departure of this study, and the embodied cognition lens is used to elaborate the phenomena.

2.2.2 Embodied Cognition in Design

Embodied cognition is a reaction of a standard cognitive science and views that cognitive processes are deeply rooted in the body's interactions with the world [4]. Key claims and themes of embodied cognition have been posited elsewhere [4–7]. This approach sits together with other areas of research: embodied, embedded, enactive, and extended (4E) approaches to cognition. They share similar perspectives of material embodiment and environmental embedding playing a significant part in understanding human cognitive process. According to Shapiro [8], the traditional approach of cognitive science does not consider the feedback as in embodied cognition. This feedback loop entails: input, processing, output which an input, processing and output. The processing would not work without the output feeds. Through this lens, designers' mind, body, and environment are considered to play equally crucial roles in design cognition. A critical analysis of the underdeveloped field of *embodied creativity* which encapsulates notions of embodied cognition and creativity reveals potentially not only how we perceive the creative process, but also the influence of body and environment on creativity itself [9].

An important concept in this lens is *affordances.* According to Gibson, they are what the environment offers animals or what the environment provides [10]. *Effectivities* are ways of acting that an animal can use to realize specific affordances; the term was coined by Turvey and Shaw [11]. Tool use is the common case to illustrate *effectivities.* Before tools are used, they are separated from the user's body. Once it is used, a tool is treated as functional extension of the user's body. In this paper, both terms are extended to the design context. Slightly different to Norman [12]'s definition of *design affordances* which are "clues to operations of things," *design affordances* are seen as what the design environment offers designers. In this paper, it is limited to the environment in which designers were during the experiment. *Design effectivities* are seen as designing acts which designers take to realize the *design affordances.*

2.3 Methodology

Protocol data was obtained through a contrived setting of final year design students in an overseas campus of a UK university. EG1 consisted of four architecture students and EG2 of four product design and manufacturing students. CG1 consisted of four students of an equal mix between the two disciplines. The data collection of experimental group arrangements was adapted and modified from Bilda et al's studies [13]. Table 2.1 illustrates design environment. Each participant was given two multifunctional design tasks and was asked to think-aloud while designing. The first task is flexible meeting space (FMS), and the second is hybrid furniture system (HFS). The orders between design environment and briefs were counterbalanced to minimize threats to internal validity. The study was reviewed according to the university's code of research conduct and research ethics. Consent was obtained from all participants in written form.

Table 2.1 Design session environment

Experimental group 1 (EG1) and EG2	Control group (CG1)
1. SK environment: 45 min of sketching session with unlimited access to externalizations 2. MI environment: 35 min of blindfolded session and 10 min of externalization session	1. D environment: 45 min of design session with offline design tools (colored pencils, markers, ruler, etc.)

After verbal data was obtained, it was segmented into design moves. One move represents one single design idea. Subsequently, data was encoded into three categories of coding scheme. They are *cognition*, *body*, and *environment*. *Cognition* codes were adapted from the Geneplore (generative and exploratory) processes of creative cognition [14]. They refer to design actions which occurred internally. *Body* codes were adapted and added from *physical* category of Suwa et al. [15] and are bodily movements related to designing. Environment codes were constructed during the previous pilot studies of fourteen participants, and they refer to actions occurred outside the body. In total, there are 12 *cognition* action codes, 9 *body* action codes, and 5 *environment* action codes.

More detailed explanations about the method of data collection, list of coding scheme, an example of how data was parsed and possible graphic outputs and statistical output derived from the online data visualization program (https://bigzhe.github.io/coded-design-analysis/) can be found in a previous discussion [16].

2.4 Discussion

The previously mentioned feedback loops between designers and environment in designing context were investigated. The authors suggest decomposition of internal and external processes is the first step to explore this interaction. Design moves are used to illustrate differences between designing activities when: (1) designers had unlimited access externalizations, during SK sessions, and (2) designers had staged access to externalizations, during MI sessions. The number of concurrent actions between categories of coded action reveals how often the interplay happened.

Three-coded actions are design moves which exhibited actions related to *Cognition* ↔ *Body* ↔ *Environment*. Two-coded actions are one of the following: *Cognition* ↔ *Body*, *Cognition* ↔ *Environment*, or *Body* ↔ *Environment*. "↔" shows concurrent actions. However, *Body* ↔ *Environment* only occurred once in one session, EG2-3_2SK_HFS, and can be disregarded. Figure 2.1 shows the occurrences of two- and three-coded actions in relation to the total number of utterances produced in 24 sessions, in three design conditions. At least, a quarter of total number utterances in each session were two- or three-coded actions across 24 sessions. The averages were SK sessions (53.51%), MI sessions (45.61%), and D sessions (59.05%). The remaining percentages were moves with only one-coded action, usually *cognition* actions. The access to pen and paper in SK sessions and offline design tools in D sessions seems to contribute to the higher number of recorded concurrent activities across mind, body, and environment. It suggests that this kind of feedback loop is paramount to be investigated. Also, it shows how designers not only dealt with internal processes in mind, but the interplay with external processes contributes to the whole complex cognition system. The most frequent interplay was two-coded Cognition ↔ Body (yellow shade in Fig. 2.1), conjecturing there was a strong interactivity between designers' mind and body (usually hands or look at the previous depictions in other sheets), in all three design

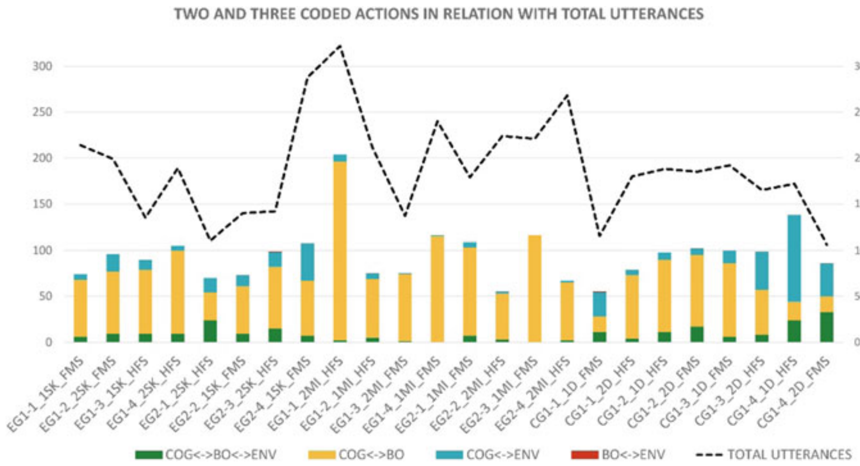

Fig. 2.1 Occurrences of two- and three-coded actions in comparison with total utterances

environments. Most interestingly, this phenomenon included MI sessions when participants were blindfolded most of the time.

A short excerpt of EG1-2_2SK_FMS (second participant of experimental group 1, the second session being a sketching session and brief was the flexible meeting space), utterance #107–#112, exemplifies this interplay. Participant EG1-2 in the previous page explored a space layout in plan view and at the same time thought in more detail about the modular piece. In move #107, she initiated a new plan, drawing to refine the space layout option. While synthesizing about the size of the proposed plan, she adjusted the drawing paper. In the next move, #108, she looked at the previous page, while recalling the functions of the little enclosed spaces, she drew off the previous page. This act of pausing and inferring information from the previous depiction was repeated in #110 and #111. These series of "bringing something physical into being" actions by materializing her thoughts are common actions. Designers do something (in EG1–2's case, drawing actions) that subsequently feed into their cognitive loop. As a result of this, new thoughts occurred. What was an output became an input for the next action, as Shapiro mentioned. The output of previously drawn depictions subsequently became an input for EG1–2.

The illustrated feedback loops are similar to what Dennett illustrated as *cognitive autostimulation* [17]. An example of an audio *autostimulation* is that talking aloud could blaze a valuable new trail between one's internal components (ibid.). Designing can also be seen as an act of *visual cognitive self-stimulation* whereby the use of drawings is readily appreciated as one technique. Clark and Chalmers in their seminal paper "The Extended Mind," explored the concept of *active externalism* as opposed to *passive externalism*. Embracing *active externalism* means agreeing on active coupling systems between human organisms and external entities as two-way interactions. The key is that external features play an important role, and if removed it, behavioral competence will drop (ibid.).

2.4.1 Interplay in Sessions with Unlimited Access to Externalizations

Eight SK (sketching) sessions were dissected into five adapted design intentions, and 16 sub-intentions derived from common human-based design characteristics [18] and patterns of simultaneous processes across mind, body, and environment were observed. It was observed that in SK sessions, distinct types of interplay were sub-design intention related. Different kinds of interplay were exhibited depending on the kinds of action designers were engaged in. They can be related to design situation, design problems, pattern of organization, generation of design solutions, or reutilization of explicit knowledge from design domains. It was also found that every interplay is constituent rather than causal. The feedback loop between *cognition* actions—*body* actions through the act of sketching—*cognition* actions through the reactions of drawing marks left from previous action—initiated another *body* action and created another *cognition* action which with *environment* actions created an iterative loop. If *body* and *environment* actions were not constituent, designers would be able to perform without them. But in this case, without these actions and once the loop is disrupted, designers would not be able to perform.

In total, there were 30 identified common patterns found in SK sessions. Due to length limitations of this paper, only one pattern (related in analogy) will be illustrated. Each combination provides a unique potential to be carried over to the next design processes. Figure 2.2 shows illustration of *design affordances* (D.A.) of SK environment. It was identified that in SK sessions, there are two possible categories of what the design environment can provide. D.A.1 which is the environment itself such as design tools, properties observed in physical surrounding, adjusted paper, and design brief also offered potentials designers could recognize. D.A.2 which is the products of *body* actions such as symbol depictions, texts, revised artifacts, newly created artifacts, previously depicted images, gesture (only those which contributed to design) offered potential to be utilized in the next moves. For instance, once a depiction was made, it left a mark on the paper and it became part of the environment. The cognition boundary in SK sessions was distributed across mind, body, and environment, depending on the type of interplay: whether it was three-way interplay or two-way interplay.

Subsequently, after realizing the affordances, *design effectivities* (D.E.) were deployed which were the identified *cognition* actions. Designers realized potentials and adjusted their behavior according to the possibilities. In SK sessions, there were three possible ways of interplay: three-coded of Cog $\leftrightarrow$ Bo $\leftrightarrow$ Env, two-coded Cog $\leftrightarrow$ Bo, and two-coded Cog $\leftrightarrow$ Env. An example of a situation intention, specifically the “dealing with analogies” sub-intention, is elaborated.

Based on the observations, information had to be retrieved before it could be used for analogy. Externally and concurrently, designers were potentially engaged with textual aids, or hand gesture, or other gestures, or making new depictions, or they attended to a previous depiction concurrently while retrieving information. At the same time, design environment such as physical surroundings and design brief

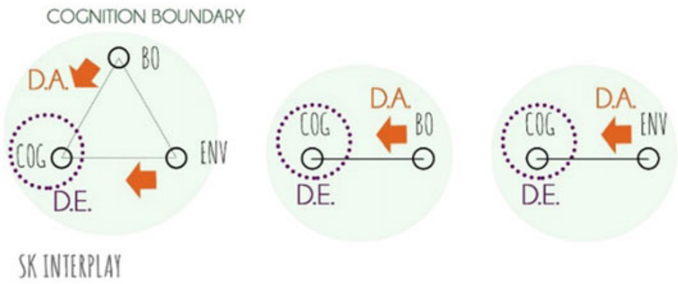

Fig. 2.2 Illustration of design affordances and effectivities in SK

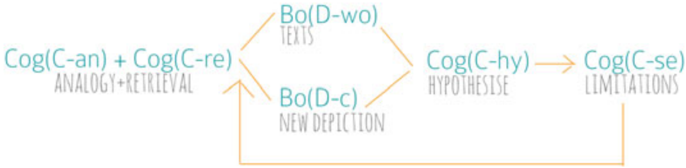

Fig. 2.3 A schematic process of possible occurrence of identified pattern

contributed to these moves. Figure 2.3 depicts an example of this identified pattern related to analogy in EG1-2_2SK_FMS session, utterance number #1–#10. It shows how analogy was used to aid hypothesis testing. The previous experience and knowledge about "flexible office" were retrieved in move #1, subsequently new depiction was made, hypothesis was made about the dimensions, limitations were considered, and next, a new analogy driven by EG1–2's previously encountered information was constructed leading to another new depiction in move #10.

2.4.2 Interplay in Sessions with Staged and Limited Access to Externalizations

Similar to SK sessions, MI sessions underwent the same treatment and design moves were classified into chunks representing design intentions and sub-intentions. The main difference in comparison with SK is that in MI sessions designers generated ideas when they were blindfolded. The blindfold was crucial to make sure that there was no visual input. During the last 10 min of the session, designers had the chance to externalize their final design proposal using the same pen-and-paper-based smartpen. As expected, the number of three-coded categories of Cog ↔ Bo ↔ Env was low due to the blindfold (only occur during the 10-min externalization part), and most interplay was between *cognition* and *body* actions, in particular between *cognition* actions and *body* gesture. In contrast to SK sessions, interplay in MI sessions was non-intentions dependent and more generic. The common pattern is any *cognition* actions concurrently occurred with Bo(M-hg)-*hand gesture* or Bo(M-og)-*other gesture.*

A broad range of *cognition* actions was deployed, and the mean incidence of interplay in occurrences in MI sessions as previously mentioned (45.61%) suggesting that designers were not confronted by difficulties when performing design actions internally. Cog(C-re)—*retrieval* action was seen to be dominant in nearly all 16 sub-intentions, suggesting the designers coped without access to externalizations by constantly recalling information. For the dominant gestures in MI sessions, they were classified into two: (1) gestures which added value to the design and (2) gestures which did not convey design messages.

Two scenarios of interplay in MI sessions were posited. The first scenario is that the interplay between mind and body was a constituent of cognition, and *body* actions were part of designers' embodied cognition (Fig. 2.4a). This scenario represents incidences when gestures conveyed design message. In a previous study, gesture was investigated and it was found that it can function as dimension thinking, spatial reference, emergent ideas, simulation tool, shapes, and sketching-like movement [19]. The second scenario occurred when body gesture did not convey design messages. Although these actions were important appendages, they were considered as causal rather than constituent (Fig. 2.4b). Hence, in this second scenario, the embodiment of design actions was not exhibited and the mind, body, and environment actions acted as separate entities rather than a holistic cognition system. In the blindfolded stage, only D.A.2 (second type of *design affordances*) from *body* actions were exhibited. In the externalization stage, the last 10 min, D.A.1 and D.A.2 can possibly be exhibited due to access to visual inputs and environment. *Design effectivities* (D.E.) were the *cognition* actions, but only occurred during the first scenario. The second scenario exhibited neither *design affordances* nor *design effectivities.* The first scenario shares similarities with the first two concepts of simultaneity in SK sessions (Fig. 2.2).

Revisiting the idea of the previously mentioned *cognitive self-stimulation*, even when access to sketching was limited, spontaneous gesture provided help to enhance cognitive activity. Sometimes, gesture conveyed design meaning; at other

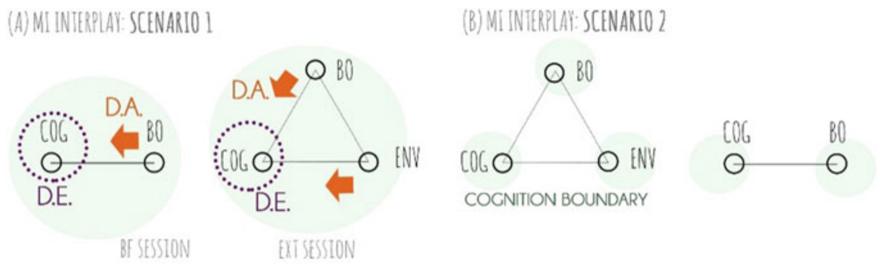

Fig. 2.4 Illustration of design affordances and effectivities in MI

times, it did not and acted as a thinking aid only. It is argued that suppressing the use of gesture will interfere with designing actions.

2.4.3 Active Self-structuring in Designing Process

Interplay in sketching and mental imagery sessions was illustrated. The feedback loops suggest that there are information flows distributed between mind, body, and possibly environment when designers are engaged in idea generation. Pfeifer et al. addressed the interaction between physical and information processes within the view of embodiment [20, 21]. The *principle of information self-structuring* laid a concept of the interplay of information and physical processes. The brain receives sensory input via the sensory receptors from both the environment and feedback acting on the musculoskeletal system and generates motor commands for this system. Based on the output from the musculoskeletal system, the environment is changed and fresh information is again passed via the sensory system to the brain in an iterative loop.

Similarly, designers can be perceived as self-structures. The brain instructs the hand to sketch (or make a gesture), and the eye perceives the sketch (or gesture). Subsequently, the brain interprets the data, and based on this new information, ideas are constantly manipulated. This highlights that in order to fully understand design cognition, it is necessary to understand the task environment, body dynamics, and also the role of design tools in this iterative process and not only what is in the designers' mind.

2.5 Conclusions

In this paper, traditional designing processes were illustrated using the embodied cognition lens. The lens has provided unexplored insights it would have been impossible to investigate otherwise if focus is solely on cognition only within the mind. In addition to the distribution of mind, body, and limited environment (due to experimental setting), characteristics of feedback loops were able to be identified. The authors argue that decomposing design moves to two-coded and three-coded actions is pertinent.

Comparison between interplay in sketching sessions and mental imagery sessions was posited. The nature of the design environment in both sessions contributed to the differences. When access to externalizations was unlimited, designers used commonly identified cognitive strategies according to their design intentions and sub-intentions. Three-coded and two-coded actions across mind and body were able to be identified. Conversely, when access to externalizations was limited and staged, designers tended to use body gesture extensively to cope with the lack of externalization. Sometimes, gestures contributed to design thinking; at other times, they aided the process of thinking. Both sessions contributed to the investigation of how the act of *cognitive self-stimulation* can possibly be enhanced with sketches or gesture and other design tools. A similar notion in the previous design research was studied, such as Schon's "*reflection-in-action*" [22] or ability to "*read-off*" sketches to clarify existing ideas [23], although it is uncommon to study the notions with a view that cognition is distributed in mind, body, and environment.

The concept of designers as self-structures was also illustrated, which highlights the need to consider how design tools or design cognitive strategies should be considered to address specific *design affordances* and serve to aid *design effectivities*. Especially with the recent developmental enhancement in design tools (digital sketching, augmented reality, or virtual reality headsets), the need to understand is even more eminent. This preliminary study is hoped to stimulate viewing designing in an alternative light and contribute to the development of the field of *embodied creativity*. The small number of participants and the laboratory-based experiments prohibited the exploration from being expanded into real design settings, but this study is hoped to highlight the important notions through the identified interplaying patterns. It is recommended that more design ecology-friendly design settings will lead to more fruitful discussion of how designers interact with their design environment.

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Chapter 3
Improving Experience at Indian Railways Reservation Counters by Digitizing the Ticketing Process

Abhishek Bose, Jyotsana and Satyaki Roy

Abstract In the current Indian Railways counter ticket reservation scenario, the applicant has to write all the journey details on the reservation requisition form and then has to hand it over to the ticket booking staff at the counter. The staff then has to re-enter those details into the computer system manually. It takes more time for the staff to type the information when the form has multiple passengers for the same journey. Though the counters work on first-come-first-serve basis but the service time at the counter window varies drastically between 4 and 6 min per applicant. This creates a much bigger problem for the applicants during Tatkal booking hours where even a fraction of second makes or breaks a journey for many passengers. With an extensive user survey of applicants and staffs at various reservation counters across the country, we identified the core reasons for non-uniformity in ticket booking timings. It was found that the major factor for this non-uniformity of ticketing time is due to variable human proficiency factors such as number of passenger names in the requisition form, handwriting of the applicant in the requisition form, and typing speed of the staff at the counter. This paper proposes a new digital system comprising of a mobile-based application and kiosks (for non-smartphone owners) that will generate a unique code for booking counter tickets. This code will help to eliminate the manual data entry of the journey details into the reservation system by the staff and make the booking process more efficient and faster by reducing the cognitive load on the staff. With this system, the service time to book the ticket at the reservation counter window will be 40–45 s regardless of the number of passengers in the list.

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3.1 Introduction

Indian Railways is the fourth largest railway network in the world with a total route length of 67,378 km [1]. Approximately, 2.3 crore passengers travel daily in trains [2]. Indian Railways also has a subsidiary branch called Indian Railway Catering and Tourism Corporation (IRCTC) that manages the catering, tourism, and online ticketing operations. As per the statistics, 42% of the reservation tickets are booked at the computerized reservation counters also known as Passenger Reservation System (PRS) counters, which means that a significant number of people are using the PRS. In 2016, the total number of reservation tickets booked was 2861.86 lakhs, out of which 1648.41 lakh tickets were booked through IRCTC and 1213.45 lakh tickets were booked from PRS [3]. Indian Railways launched Tatkal Scheme to book journeys at a very short notice. If we consider the number of Tatkal tickets then as per the existing Tatkal Scheme as generated by Indian Railways in the year 2012, 1.71 lakhs seats/berths are available under Tatkal quota which is 14.75% of the total seats/berth available [4]. Out of this 1.71 lakhs seats, approximately 1.30 lakh [5] seats are booked through IRCTC and the remaining 41,000 seats are booked through various PRS counters all over the country. There are 3422 PRS counters [6] all over India which means that only a mere 11.98 seats are being currently booked at a given PRS counter.

3.1.1 Problems in Existing Model

Five direct observation sessions at reservation counters of Kanpur Central and New Delhi were conducted. It was observed that an applicant joining a queue of six people has a waiting time of roughly 20–24 min in the queue and 3–4 min of service time at the counter window. Also semi-structured interviews were conducted with 25 applicants and 6 booking staffs to find out the pain points and challenges faced by them. The ticket allocation at PRS counters is completely based on first-come-first-serve basis. When the applicant reaches the service window, he/she hands over the requisition form to the booking staff. The staff then manually enters the data into the system. If we take a closer look, the individual service time for each applicant varies drastically with number of passengers in the requisition form. At a superficial level, it is true that the PRS counters work on first-come-first-serve basis, but when we take a deeper look we find that the service time for each applicant greatly varies due to various factors such as:

- *Number of passengers in the requisition form* (more the number of passengers, more the time is taken to input the data into the system by the staff).
- *Handwriting of the applicant* (due to illegible handwriting, more time is taken to understand and enter the data into the system by the staff).

- *Typing speed of the staff* (slower the typing speed of the staff, more the time is taken to enter the data into the system by him/her).
- The cash transaction time is also subjected to *availability of change* with both the parties.

Some of the other problems that were observed are as follows:

- Ticket booking at the PRS counter is a very time-consuming process. The situation worsens during the Tatkal hours as delay of even a second can either make or break the journey for many passengers.
- *Long length of queue* frustrates the applicants. 70% of the applicants are concerned about the waiting time [7].
- Other problem is *manual data entry* of the passenger's information into the system by the staff. The process of manual data entry is a time-consuming and laborious process.
- The *existing system has loopholes* which make it easy for ticket agents to book tickets illegally and sell them at much higher prices.

3.1.2 Problem Statement

The objective of the paper is to propose a solution where booking a ticket at a PRS counter will take minimal and uniform amount of time irrespective of the number of passengers in the requisition form.

3.2 Research Methodology

User scenarios help in understanding how users use the system. It helps in knowing the problems and situations better. After talking to the applicants and the staff members at the counter, few user scenarios were noted down as follows.

3.2.1 User Scenarios

Scenario 1: Ram who is a retail shop owner stays at Varanasi. Ram receives a call and gets to know that his brother who studies in Delhi has been diagnosed with jaundice and he has to be admitted in a hospital at the earliest. So, Ram goes to the counter to book a Sleeper class Tatkal ticket for himself and his mother. Ram reached the counter at 10:30 a.m. and found that there are already two people in the queue ahead of him. However, Ram was disappointed to be third in the queue but he was still hopeful about booking a ticket successfully. When the Tatkal window opened, unfortunately, the booking staff took a lot of time to read the handwriting of the person ahead of him (who was booking ticket for six passengers) and wasted 10 precious minutes for booking a single ticket. At last when Ram's turn came, unfortunately, there were no more Tatkal tickets left. Ram had to return home sadly and decided to catch a bus instead.

Scenario 2: Shyam Lal is an Indian Railways employee who books ticket at Ticket Reservation Counter. Every day, thousands of people visit the counter to get a ticket. Manual entry of the requisition information into the system from the paper requisition form filled by applicant looks futile and waste of time. Many applicant's handwriting is illegible at times. Thus, making the process of booking a ticket even more slow. Often, the process worsens, if it happens during the Tatkal hours.

3.2.2 Insights

- On an average the requisition forms contain names of 3.2 passengers.
- Average time being 4 min 30 s for normal tickets, and 3 min 40 s for Tatkal tickets.
- Less than 20% applicants are able to successfully book a Tatkal ticket at the PRS counter.
- 80% of the applicants who come to the PRS counters have smart phones with Internet connectivity.
- 85.9% of the population have Android smartphones [8].
- Manual data entry process increases cognitive load on the ticket booking staff.
- Online booking of tickets has increased drastically in last few years.
- The ticket booking counters can not be removed as still many people do not have access to the Internet and smartphones.

3.2.3 Top Findings

- Existing ticket reservation system is slow.
- The variable human proficiency levels such as typing speed of staff, poor handwriting of applicants, and manual cash transaction timings are instrumental in making the process of booking reservation tickets slow.
- Success rate of Tatkal booking is low at the counters.
- Applicants have to wait for a long time for their turn to come.

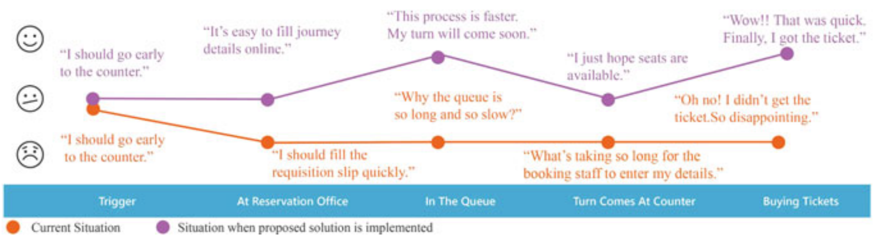

Fig. 3.1 Customer experience map in existing model and proposed model

3.2.4 Opportunity Areas

- How might we make existing ticket reservation system faster?
- How might we make process of filling passenger information faster/easier for the staff at the counter?
- How might we eradicate the variable human proficiency levels such as slow typing speed, poor handwriting of applicants, and cash transactions?
- How to maximize the Tatkal ticket booking success rate?
- How might we reduce waiting time of the applicants at the counter?

3.2.5 Customer Experience Map

See Fig. 3.1.

3.3 Proposed Model

To *eliminate the manual data entry of the journey details* into the reservation system and making the booking process more efficient and faster, we put forward the idea of *digitizing the reservation requisition forms.* This system will ensure that the time taken to book any ticket (regardless the number of passengers in the list) will be the same.

The reservation requisition forms will be available online on a *mobile application* and also at the *installed kiosks* in the railway reservation office. The applicant can fill passenger details and train details online using the mobile application beforehand. On submitting the form, all the entered information gets stored in the Indian Railways database and the applicant receives a *unique code number* on his/her phone. For booking the ticket at the counter, the applicant needs to show this code number so that the booking staff can retrieve the requisition information and

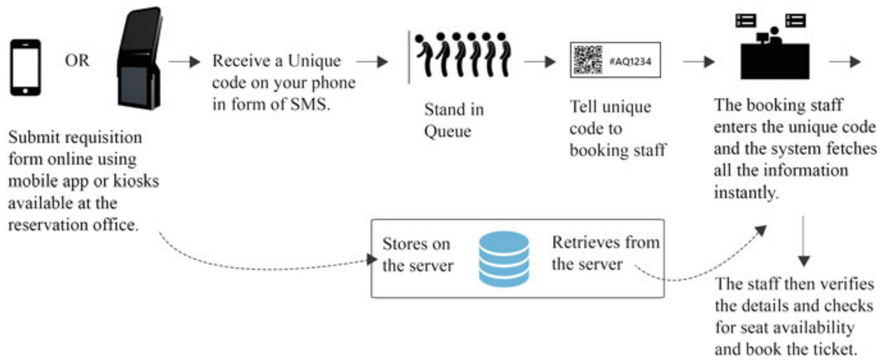

Fig. 3.2 Proposed model overview

further proceed to check seat availability in the train and then book the ticket. This eliminates the task of re-filling the data from requisition form into the system. Thus, reducing the *waiting time of the applicants and making the ticket booking process faster at the same time* (Fig. 3.2).

Why Indian Railways is still not a paperless model?

The ubiquitous use of paper is obvious due to its inherent physical properties such as tangibility and portability making paper the primary medium of data collection over the centuries. A study [9] revealed the main reason (described below) due to which organizations find it undesirable to deviate from manual data entry process, but these do not hold true for Indian Railways in the current scenario.

- Firstly, due to poor Internet connectivity, the organizations are unable to upload data to the server. But in India, there is a good amount of high-speed Internet available. India ranks 76th out of 133 countries with an average Internet speed of 18.82 Mbps [10].
- Secondly, it says that need for digital data entry is not much. But according to this survey [3], everyday, 3.32 lakh tickets are booked at PRS counters via paper-based requisition forms.
- Thirdly, there may be political or security reasons. But this data is not confidential and can easily be stored in digital form.

3.3.1 Salient Features

- Paper-based requisition forms will be fully *digitized.*
- This digitization will be in the form of *Mobile-based application and kiosks* at the railways booking offices.
- In the digitized requisition form, applicant has to enter all the details such as Journey Details, Passenger Details, Train Details, and Applicant Details.

- Applicants who do not have access to smartphones will fill the requisition form at the reservation office kiosks. After the submission of the form, a *unique code number* will be sent to the applicant's mobile via SMS.
- Applicants who have access to smartphones will fill the requisition form using the app and submit it to receive a unique code number on their *mobile number* via SMS.
- There will be 2–3 *kiosk* at all the reservation offices. The kiosk will employ a staff to assist the applicants.
- These kiosks will run 24 *by* 7. Same with the mobile application as well.
- The generated code will be valid till reservation office closing time of that day.
- In the requisition form, the applicants can fill up to 3 *train preferences* along with class of travel.
- After the code is generated, the applicant will stand in the queue at the booking counters.
- The queues will operate on *first-come-first-serve basis.* When the applicant's turn comes, he/she just has to show the code number to the booking staff.
- The booking staff enters the code number and system fetches all the information that was submitted by the applicant via app or kiosk.
- The staff then verifies the details and *checks for seat availability.*
- The system will ensure that one applicant can fill *maximum of* two requisition forms in a day.

3.3.2 Novelty of the Proposed Solution

Swachh Bharat Mission: This is the largest cleanliness initiative run by the Government of India whose objective is to keep India's urban and rural areas clean.

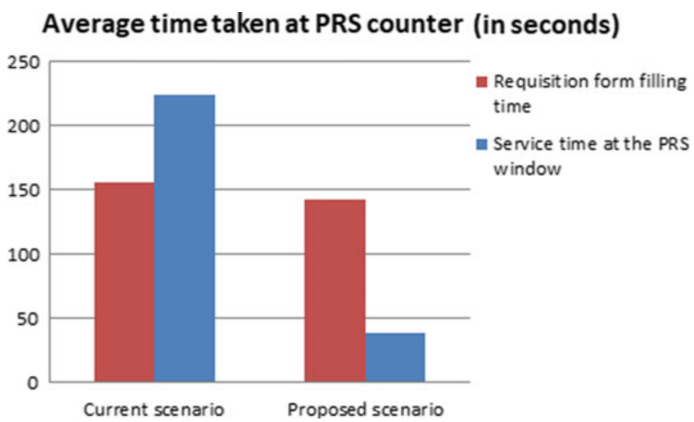

Fig. 3.3 Comparison of average time taken at PRS counter in current scenario and proposed scenario

Our proposed solution contributes to "Swachh Bharat" [11] campaign as this ticket booking process is paperless.

Digital India: It also contributes to "Digital India" [12] campaign by digitizing all the process in booking a ticket at a PRS counter. Hence, meeting the main objective of Digital India Initiative. Our design is user-friendly and intuitive. The interface will require much less time and cognitive load on the part of the booking staffs to understand and learn.

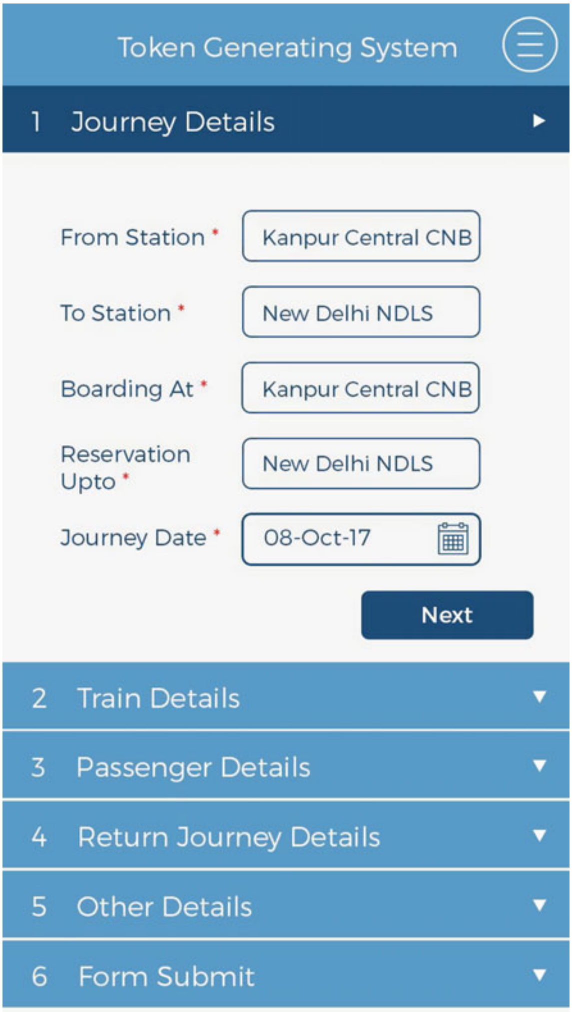

Fig. 3.4 Journey details are entered in this module. Only the current module is active

3.4 Results

In order to calculate the average time taken to book a ticket in the proposed scenario, an Android application was developed and tested with 15 participants by asking the participants to fill the digital requisition form. The time taken to fill the form was noted and average time was calculated. Further, this data was compared with the data that was collected at the PRS counters.

Similarly, the service time was also calculated by simulating a similar environment to that of an actual PRS where the applicant had to show the unique code number to the booking staff and the staff entered it into the system to fetch the applicant's records. This action was carried out with 15 participants, and the

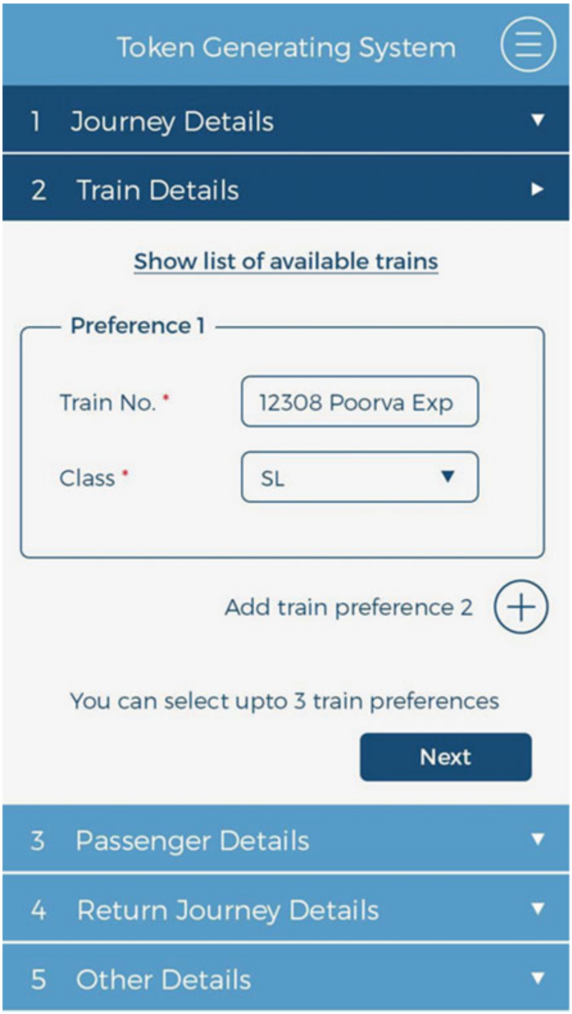

Fig. 3.5 Applicant needs to enter the train details. They can enter up to three train preferences

average time was calculated. Waiting time in the queue was ignored as it is dependent on the number of applicants in the queue. Also, cash transaction time was ignored as it is common for both the cases.

As observed, the average time taken to fill the digital requisition form was 13 s quicker than filling the paper requisition form. Also, the average service time in the proposed scenario was found to be just 39 s in comparison with the average service time in current scenario, which is 224 s approx (Fig. 3.3).

Android platform was chosen to develop the application because it is known for its power, speed, scalability, and performance. Android platform allows the development of application in a very easy way as Android is a completely utilitarian

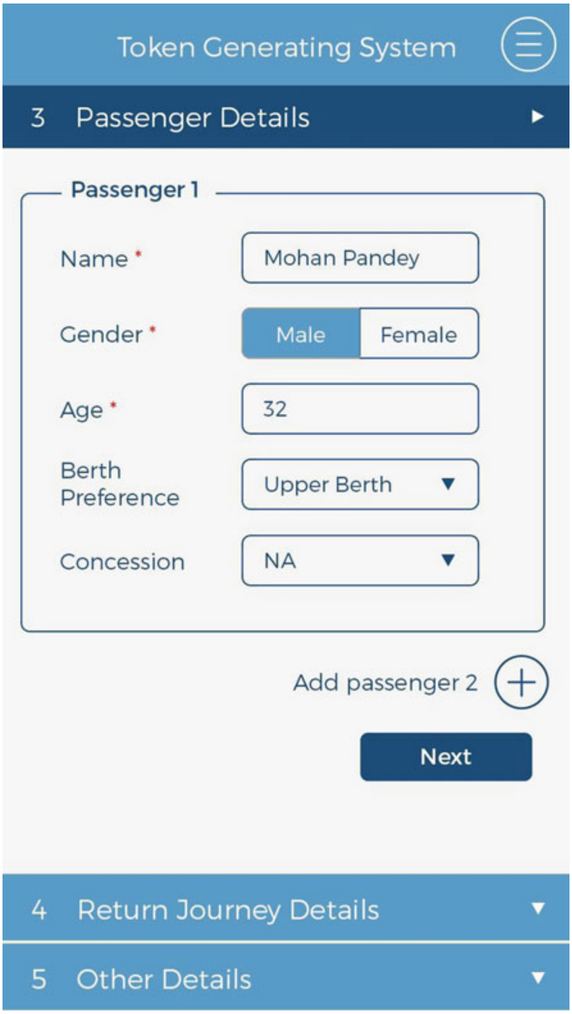

Fig. 3.6 Applicant can add up to six passenger details

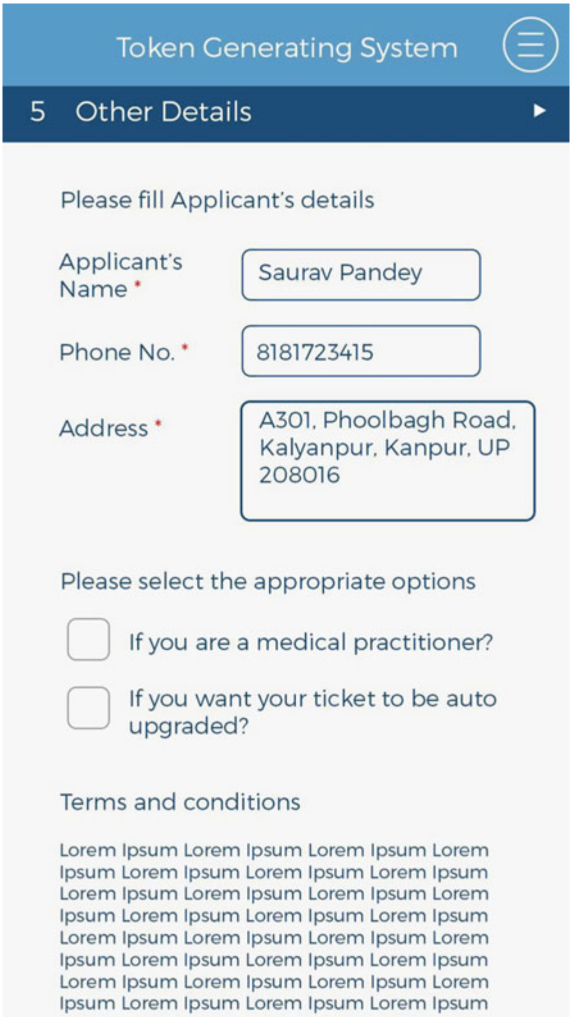

Fig. 3.7 Other details are entered in this module

feature-packed platform. One of the greatest features of Android is its open-source nature.

A recent global market study figures as released by Statista [8] show that 85.9% of the global market is captured by Android. And iOS smartphones captured only 14% of the global market. This study also shows that how the market of Android has grown over the years from 22.7% in 2010 to 85.9% in 2017. Some of the screens for the mobile application are shown in Figs. 3.4, 3.5, 3.6, 3.7, 3.8 and 3.9.

Below are some of the screens for the interface of the ticket booking staff at the PRS (Figs. 3.10, 3.11 and 3.12).

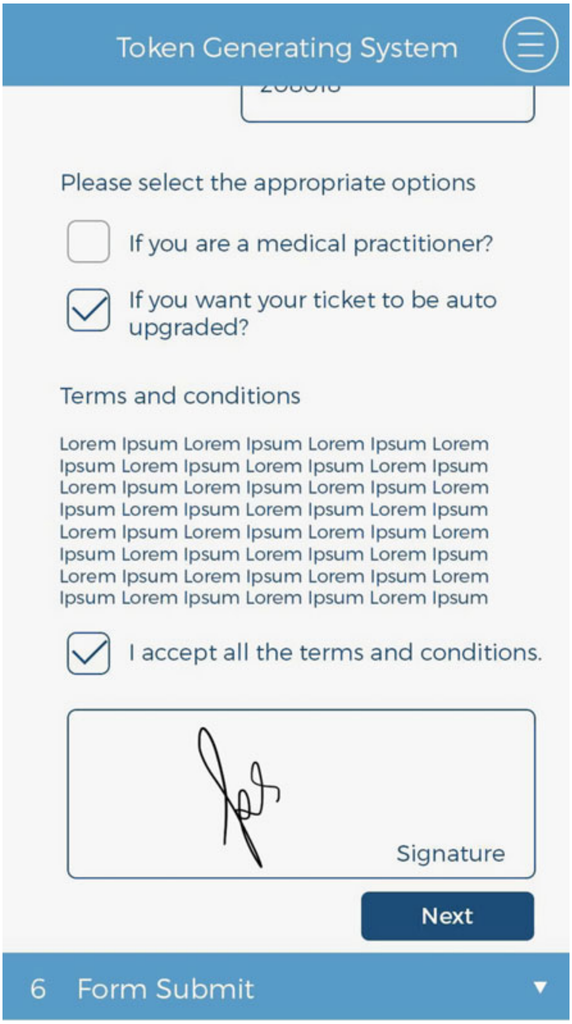

Fig. 3.8 The applicant needs to digitally sign the declaration form

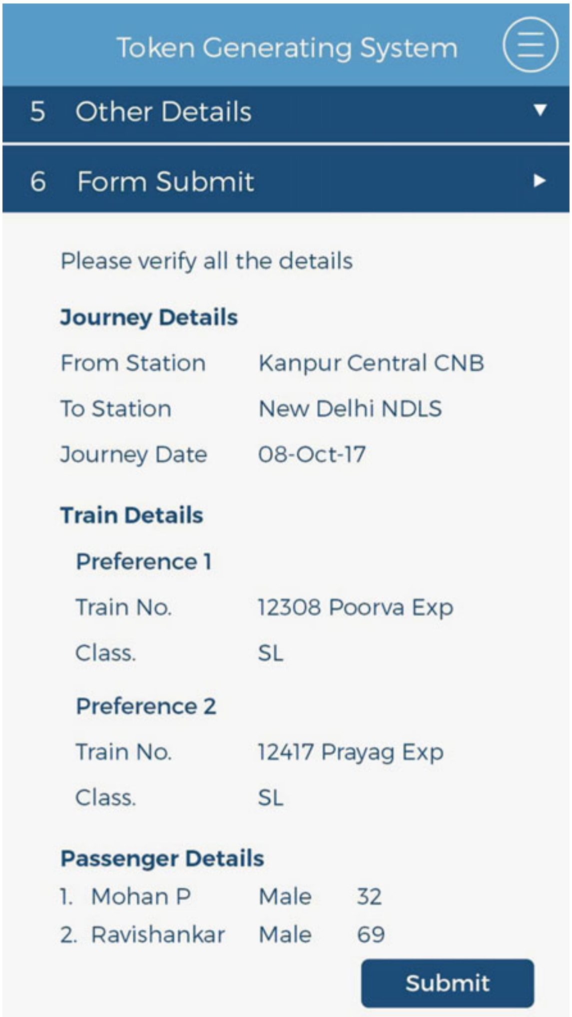

Fig. 3.9 This is the final verification screen. Then the form can be submitted

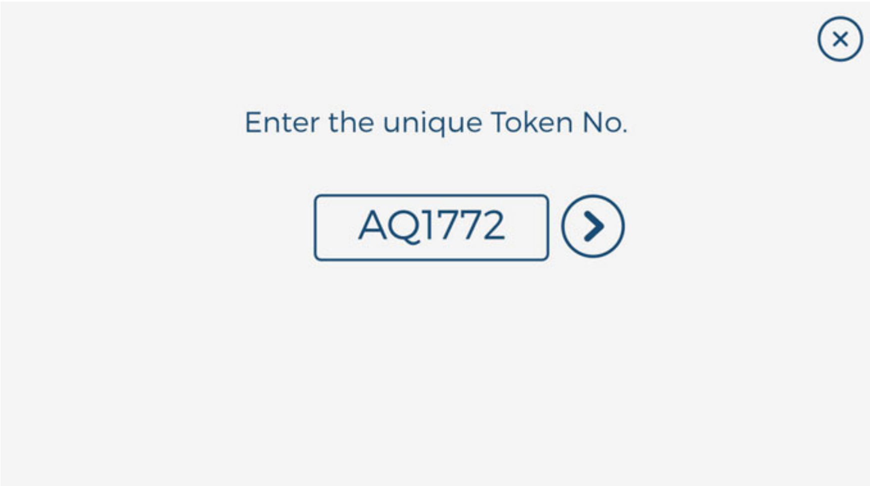

Fig. 3.10 The code number is entered to proceed with booking of the ticket

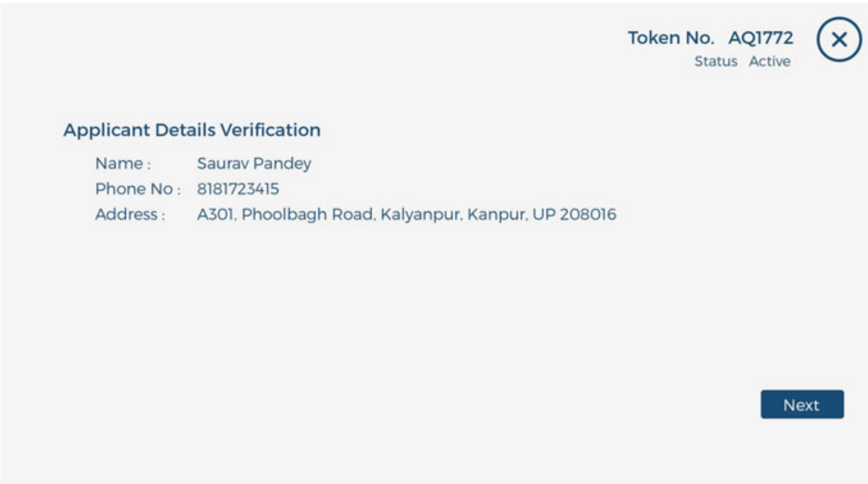

Fig. 3.11 The staff verifies the applicant details and the code number

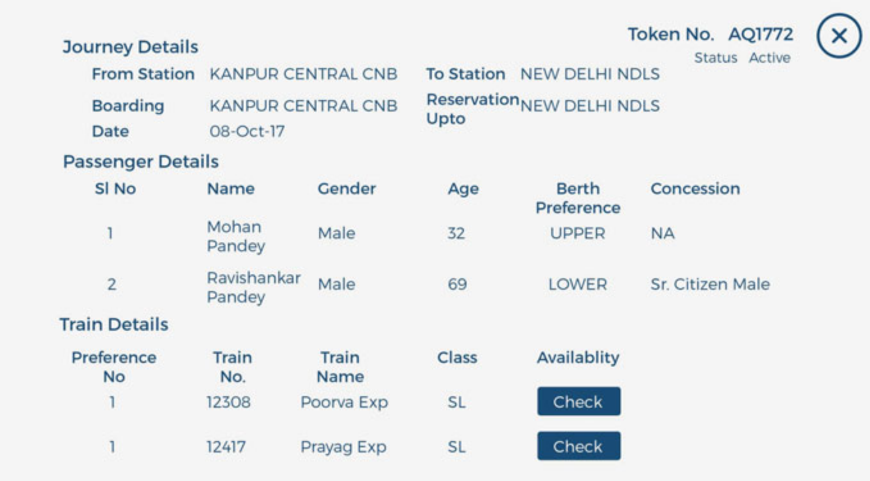

Fig. 3.12 The booking staff goes through the journey details, passenger details, and train details and proceeds to check availability of seats in preferred trains. If seats/berths are available the staff books the tickets

3.5 Conclusion

Paper-based reservation requisition forms are widely used across all the PRS counters of Indian Railways. Manual data entry is a very slow and laborious process. The test results show that the average service time at the PRS counter window has been reduced by 5.7 times i.e., from 224 s (current scenario with paper requisition forms) to just 39 s (proposed scenario with digital requisition form). This reduction of time is very crucial, especially during the Tatkal hours. Hence digitization of the requisition forms is very much needed.

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Chapter 4
Out-of-the-Bucket Thinking Among Students with Heterogeneous Background While Solving Creative Problem by Using Combinatorial Tool

Avinash Shende and Amarendra Kumar Das

Abstract Master of design students at IIT Guwahati come from four different backgrounds—these are technical background, architecture background, fine arts background and design and fashion design background. The students were given a problem of technical in nature to be solved without any external support. The same set of students was given same problem to be solved introducing a combinatorial tool (designed based on visual stimuli and forced fitting). The introduction of combinatorial tool at the early stage of problem-solving process changed the approach from linear to nonlinear thinking, which affects the overall outcome of the creative problem-solving task. The paper will discuss the observations made on the results of both the tests and tried to establish the comparative statement between the results.

4.1 Design Education in India and Creativity Issue

The first school of design in India is National Institute of Design (NID) established at Ahmedabad, India, in 1961. The intake for this institute is school-leaving students after passing higher secondary school certificate (HSSC) examination. The teaching methodology followed at NID was from Bauhaus and Ulm, both schools of design from Germany, which best suited for the need of industrialization that was the need of India during the 1960s. Even the tutors at NID used to visit from Europe and USA to name with Charles and Ray Eames, George Nakashima, and Anna Castelli. In 1969, Industrial Design Centre (IDC) was established in a premier technical institute, Indian Institute of Technology Bombay (IITB). The intake to

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IDC is lateral entrant, mainly engineering and architecture background. The design education imparted at IDC is different than NID as it is a part of technical institute, and the main philosophy of teaching was focused to merge design and technology in the curriculum at the postgraduate level. Further, NID also started postgraduate diploma course where the entrant is from engineering and architecture background. Other design schools, which were established thereafter, are in IITs, such as design program at IIT Delhi in the year of 1995, Department of Design at IIT Guwahati and IISc Bangalore in the year of 1998, design program at IIT Kanpur and IIITDM Jabalpur in the year of 2004. There are few more IITs, IIITs, and technical universities which are planning to start design schools in the near future. All IITs intake reached to 25–27 numbers of students. But the fact is that India still has not reached enough number of designers, that is, less than 20,000 in a country of population 1.2 billion. Design program in all these IITs is following the same educational pattern either from NID or IDC. Initially IDC, IIT Bombay, and IDDC, IIT Delhi, started entry for students with only engineering and architecture background; further, they opened up the entry criteria for design (and fashion design) and fine arts background candidates.

Bhasker Bhatt commented on the design program in India that is designed toward producing graduates for the industries, but not creative individuals or innovators. There is a need to motivate design teachers to shift down to the bottom of the hierarchical where innovation and creative thinking are encouraged [1]. The statement was further supported by Jagdish Khelkar mentioned that ‘we must acknowledge that there is a step before problem solving itself, namely to attempt define a problem. We must teach students how to define problem and problem setting and solving creatively. All these inputs are missing from our educational framework’ [1]. The study on curriculum of design schools in India establishes that there are very less emphasis given on problem framing, or identification of problem, hardly a course on creativity appears in curriculum, rather more on skill set courses. So the question is whether creativity can be taught? And so is there a time to restructure the curriculum of design program and make it stronger to foster creativity among students? especially when the students are of four different backgrounds. Is there any way to inculcate creative thinking among students if there is difference on creativity among students with different backgrounds? Such questions in relation to creativity issues and design students with heterogeneous background have rarely been addressed. The research questions become important to understand that whether there is really a difference on creative thinking among students with heterogeneous background? And whether some effort is required to compensate that? The findings may lead to understand that whether there is a need to relook curriculum of design that may incorporate more courses on creative thinking and support for problem setting.

Overall, the intention in design education is to regard creativity as mainly a process that can be taught. However, the extent to which creativity is enhanced by means of education remains to be further dwelled upon. The entrance for design program is through an aptitude test ‘CEED’ examination and despite the interpretation where ‘aptitude’ avails for ‘imagination’ that is misused as identical to creativity, as quoted by Denel that 'one should realize that imagination's relation to creativity exists because it is a priori to it' [2]. This shall be the main idea underlying design education that aims at fostering creativity. However, the matter as to how this can be implemented in the first-year design courses still needs further thought and experimentation. Hasirci and Demirkan [3] assuming that creativity is a skill that can be learned and taught, the question of how creativity can be enhanced or how one can be taught to be creative in design problem solving has been a challenge of design education. The survey report on the future of design education in India [4] published by British council in India stated that almost all institutes developed the learning outcomes for their courses and a small percentage of institutions plan to develop it in. They support problem-based learning and encourage peer learning among their students.

In the first year of design education, as the basis of design education, the students enter a visual world to bring creative solutions to design problem task given, which are generally characterized by an ill-defined structure. For an ill-defined problem, the goal may be undefined and the path to solution may be multiple. Those alternative solutions might be too many, and best solution might not be single [5]. Goldschmidt and Sever suggested that a creative solution for an ill-defined problem is a trouble for most of the novice design students, if not all [5]. In the absence of clearly and precisely defined teaching and learning tools, a novice design student is expected to develop skills to solve such design problems through 'learning by doing' or 'trial and error.' However, such experiential teaching traditions may fall short to effectively transfer the instructors' knowledge and experience, about how to solve creative problem and how to reason about designing, to students who aim to gain knowledge to solve ill-defined problems. Given that, there is necessity to develop teaching tools and maybe there is a need to look for some tools that might be used as powerful teaching aids in the first year of design education, and to support this, the following methodology has been adopted.

4.2 Method Adopted

A mixed method approach was used by which qualitative data were collected. Two tests, T1 and T2, were employed among students with heterogeneous background under two different conditions. The subject selected for both the tests is same set of students with heterogeneous background who joined master of design program at Department of Design, IIT Guwahati, of 2013 batch. The total number of students is 27; out of 27 students, 12 belong to engineering background, 4 from architecture background, 5 from design background, and 6 from fine arts background.

Test T1 is conducted without any external support condition, and test T2 is conducted by introducing combinatorial tool named 'idea wheel' at the early stage of creative problem solving. Both the tests were conducted to compare the

Table 4.1 Design problem 'tool for washing clothes'

Context	After joining master of design, in the hostel you are washing your clothes by hand, using buckets and detergent
Problem-solving task	Design a tool, which will assist you for this task
Function	Washing clothes using manual energy
Design attributes	1. Easy to use with minimal effort 2. Feasible in terms of manufacturability and cost-effectiveness

qualitative differences in idea generation between the students with heterogeneous background without and with introducing combinatorial tool. And the design problem for tests was prepared based on the context of a problem faced by the students' everyday while washing clothes in the hostel (Table 4.1).

Tests started with orientation to problem-solving task with a brief introduction of design problem, performed by the students leading to qualitative analysis of the outcome and assessment of creativity through consensual assessment technique. The difference between tests T1 and T2 is an introduction of a combinatorial tool during test T2 between orientation and problem-solving task. Design problem given was the same in both tests T1 and T2, whereas the time gap between tests T1 and T2 is more than 15 weeks.

4.3 Modified Approach

Test T1 was performed by the students adopting classical creative problem model suggested by Amabile, and the model has been further developed in the context of generating ideas based on the framework outlined by Mathias [6], who suggests that the novice designers omitted some important aspects in their process of idea generation when compared and contrasted with the problem-solving process undertaken by expert designers. Problem-solving task involves initial preparation before entering into the phase of idea generation. Hence, more time is spent, and more preparation is made in between orientation of problem task, preparation, and creative idea generation.

Figure 4.1 indicates the modified Amabile model that is proposed in this research by employing combinatorial tool to facilitate certain cues in between the stages of preparation and idea generation in test T2, which acts as a diversion to the flow of creative process and provides visual stimuli. This helps to generate ideas fluently and with flexibility, and at this stage, students would prefer to spend more time.

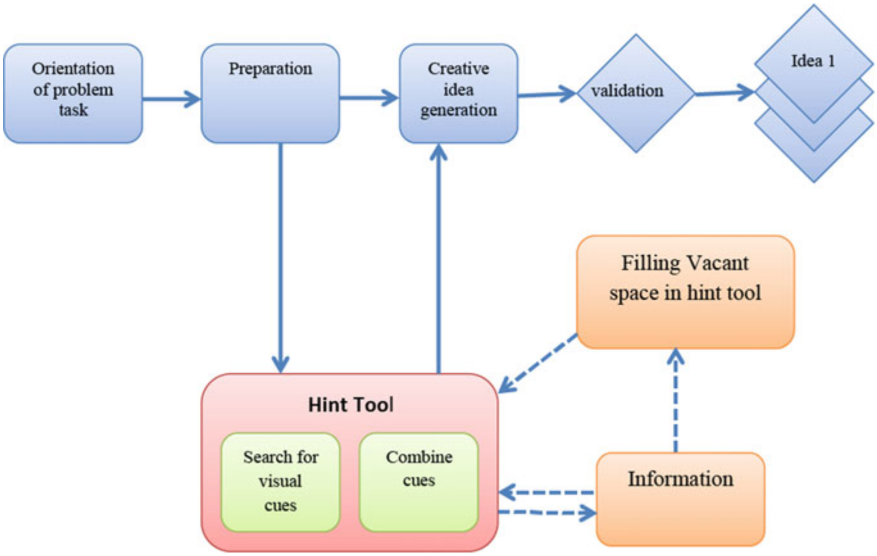

Fig. 4.1 Proposed model of creative process using combinatorial tool at the initial stage of Amabile model

4.4 Observations and Discussion

Test T1 Results: Creativity Without Any External Support Condition
In test T1, there are total 27 students' responses; out of them, 20 students' responses show that they started thinking about 'bucket' as the primary object at the early stage of problem solving. Figures 4.2, 4.3, and 4.4 show response sample sheets of three students with different backgrounds. Most of the students tried to solve problem by designing mechanisms and machines, which are attached to the bucket. In this test, the idea of using bucket is very obvious which occurs at an early stage of idea generation process without using any tool, and they fixed to it. Very few students' responses showed diversion from the idea of using bucket and looked for other hints. A student tried to move away from such fixed thinking and used to connect hand gloves with bristles to create new tool for washing; such novel connection is non-obvious, and so the raters valued it highest among all the responses. Students' capacity to define problem at the initial stage of problem solving is considered to be very low in test T1, where they tried to break given problem into other problems which they considered important to be associated with the main problem. Students tried to solve associated problem collectively by combining them as mentioned by one of the students given below.

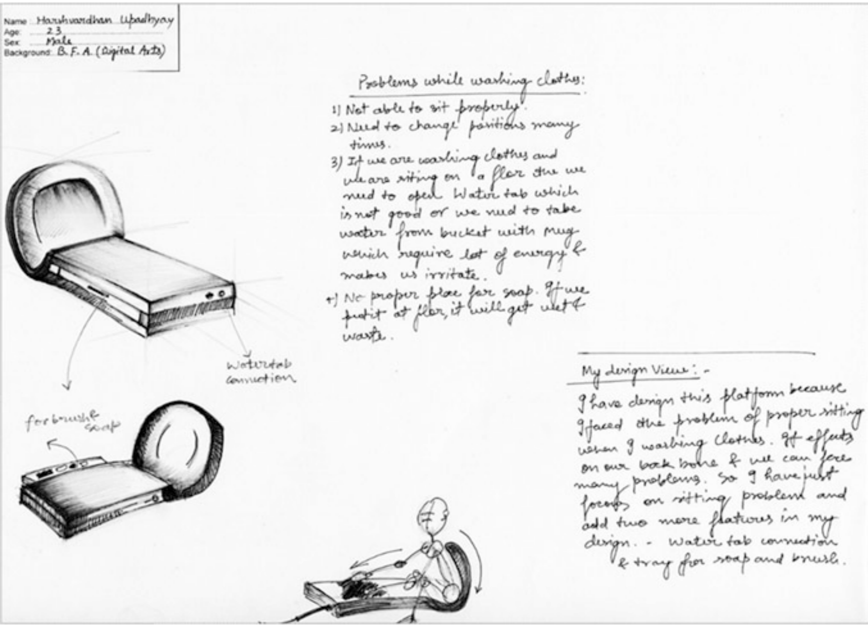

Fig. 4.2 Student 1 response sheet during test T1 without any external support

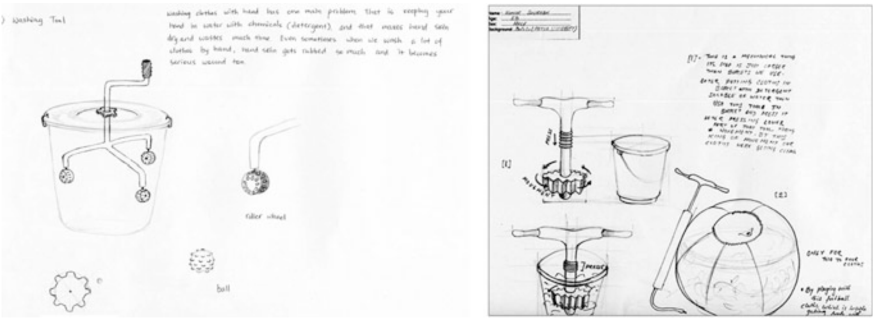

Fig. 4.3 Student 3 response sheet (left) and student 4 response sheet (right), during test T1 without any external support

Student 1 Response: Where Student Wrote About Problems While Washing Clothes

1. *Not able to sit properly*
2. *Need to change position much time*
3. *If we are washing clothes and we are sitting on floor then we need to open water tap which is not good or we need to take water from bucket with mug, which require lot of energy, and makes us irritate*
4. *No proper place for soap. If we predict at floor, it will get wet and waste.*

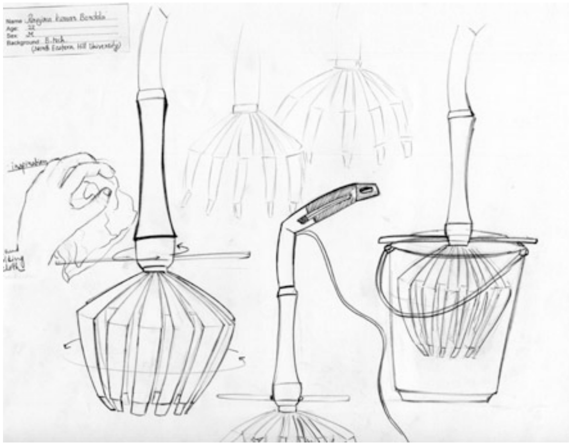

Fig. 4.4 Student 5 response sheet, during test T1 without any external support

Diversion from the main problem to solve other problems budded from the original problem; the student is from fine arts background.

Students with technical background possess the capacity to break the process into steps and tried to solve them by clubbing them together as presented below.

Student 2 Response: Discussing About the Washing Process

'*The washing process is mainly composed of following 4 steps.*

(1) *Soaking*, (2) *Rinse*, (3) *Washing off the detergent*, (4) *Squeezing off the excess water.*

Considering the traditional methods as well as the modern day methods, the mechanism of the two can be combined came up with a tool for washing clothes manually.'

The student tried to list down the tools used in traditional washing and the attribute in relation to modern day washing i.e. washing machine. And finally created a brief as follows.

1. *Taking two buckets such that one of them fits inside another bucket*
2. *Lining the walls of inner bucket with bristles*
3. *Providing handles to drive the to and fro movement of the inner bucket*
4. *Providing holes on the floor of the outer bucket to drain off the excess water.*

Student whose background is technical tried to connect the idea of washing machine with bucket; the problem-solving attitude is found to be more complex and problem focused. The ideas that emerge in such cases are non-feasible and less appropriate. The student tried to fix to his first idea and stopped looking for any more optimal options.

Student 3 Response: Discussing About the Problem Related to Irritation '*Washing clothes with hand has one main problem, that is keeping your hand in water with chemicals* (*detergents*) *and that makes hand skin dry and wastes* *much time. Even sometimes when we wash a lot of clothes by hand, hand skin gets rubbed so much and it becomes serious wound too.*'

This respondent is a girl student of design background who genuinely recollects her own experience of irritation on skin while washing clothes with her hand in the hostel, so she considered this issue as a basis for solving problem and generating ideas, where she tried to isolate hands touching the solution of detergent and water as shown in Fig. 4.3 (left). This student fixes herself to the subproblem and did not look for any other possibilities.

Student 4 response:

'*This is a mechanical thing its size is just larger than bucket we use*,

After putting clothes in bucket with detergent soluble of water then use this tool in bucket and press it after pressing lower part of that tool taking movement. By this kind of movement our clothes were getting clean.'

Although this student is from fine arts background, his response to this problem is very technical in nature as shown in Fig. 4.3 (right).

This shows that if the problem is technical in nature, the students try to solve them technically irrespective of the background of students. Another student with fine arts background tried to convert bucket into washing machine by incorporating power motor.

Figure 4.4 represents the response sheet of architecture background of student 5, where he tried to solve problem thinking of designing power-operated gadget. The response is more focused on power-operated gadget and out of the scope of given problem that is designing a tool for washing clothes and not machine.

Test T2 Results: Creativity Under Condition with Idea Wheel

In tests T2, students altered their approach completely and they tried to adopt solution-focused approach by using combinatorial tool 'idea wheel.'

Description About Idea Wheel: The idea wheel has 12 sections—s1, s2, s3, s4 … s12 (see Fig. 4.2). Every section are filled with familiar objects, except s10, s11, and s12. One may combine any section 'sn' for any number of time to create a new tool. For example, (s1 + s5) gives a brush for washing clothes, and (s1 + s6 + s9) has led to an absolutely new tool. Additionally, idea wheel encourages to add any familiar object in s10, s11, s12 by the user; this may turned out to be an useful contribution in idea wheel to generated new idea [7].

Student 3 response sheet shows drastic change in thinking as shown in Fig. 4.5 compared to the same student's response shown in Fig. 4.3 (left). The student generated five number of ideas; out of them, three ideas are non-obvious and workable. The student expressed her views about the advantages of using tool while solving problem that helps for combination of the visual hints to generate ideas within a stipulated time period. The quality of ideas generated indicates that the student got proper direction to think at an early stage of the problem solving and there is less sign of diversion of focus from the problem to be solved; in other words, the tool made its position to define problem explicitly and helped student to employ solution-focused approach.

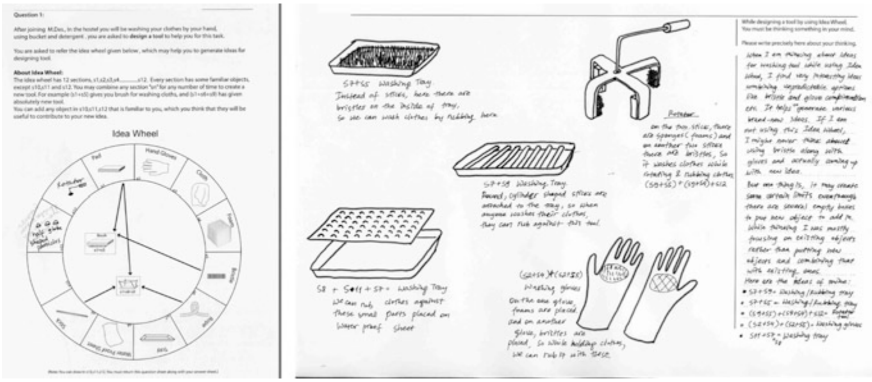

Fig. 4.5 Student 26 response sheet, during test T2 with idea wheel

The response sheet presented in Fig. 4.4 has three portions. Extreme left-side portion is a question sheet with combinatorial tool which helps for problem solving, i.e., idea wheel given to the students as a question paper. Middle portion is a space for sketching ideas generated while solving problem, and extreme right-side portion is for writing thoughts that emerges in mind during idea generation process for qualitative analysis. The response sheet in this form has been presented to the raters for evaluation and analysis.

Student 4 Response Sheet Where Student Tried to Think About Simple Tool
'*The First thing that hit me was how to simplify/aid the process and yet make it equally effective or even more so*

Then I thought of the process of washing

- *many people do not know to wash clothes—they simply put detergent on water and rinse it and dry*
- *using a brush is cumbersome as it requires extra effort*
- *This led me to think of combine the glove and the bristle*
- *A user who does not know how to wash clothes also can do so by simply rubbing his hands together on the cloth with his hands*
- *The brush has different bristle in different areas keeping in mind the different functions of the palm and fingers when washing.*'

Figure 4.6 shows response sheet of student 4 who tried to combine hand gloves with bristles, and for idea number 2, student tried to fill vacant section s10 in idea wheel with perforated sheet and tried to combine it with foam. From the early stage of idea generation, student tried to focus on the simplicity of the tool and concentrating the action of washing is as easy as rubbing hands together. Here, students understood the importance of simplicity and tried to generate ideas for designing tools those are workable and non-obvious in nature.

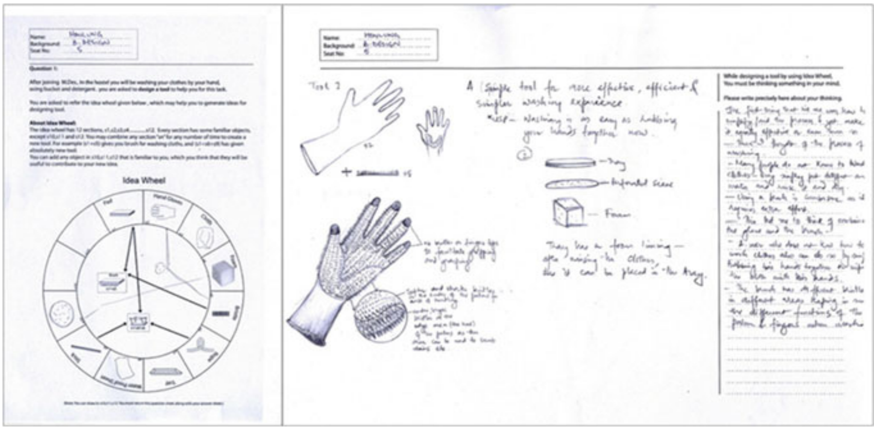

Fig. 4.6 Student 4 response sheet, during test T2 with idea wheel

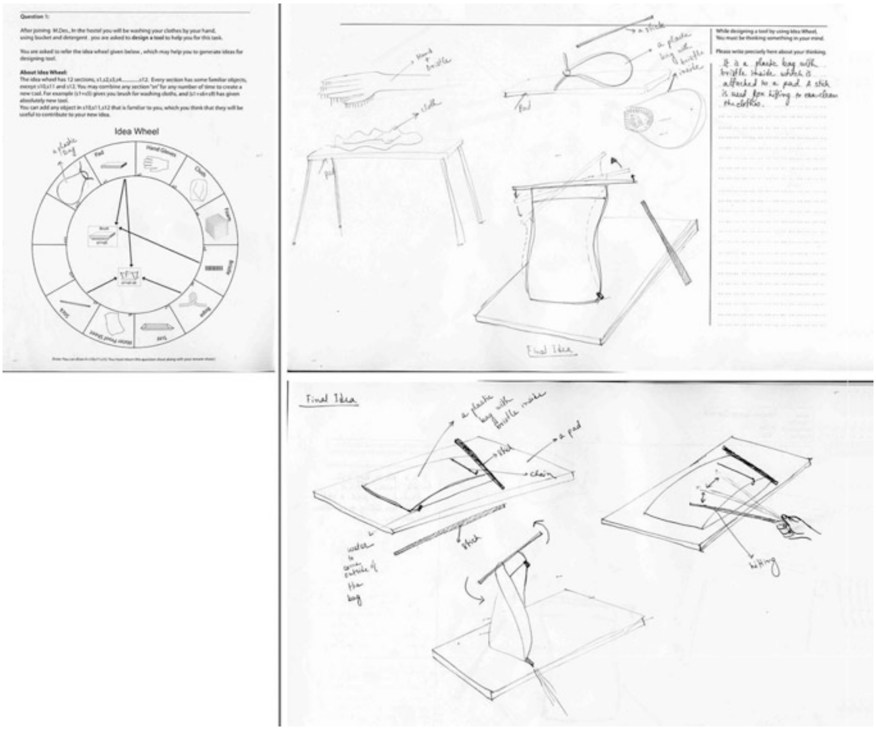

Fig. 4.7 Student 5 response, during test T2 with idea wheel

Student 5 Response Sheet
The student belongs to architecture background; he filled the vacant section s12 in idea wheel with a plastic bag. He connected plastic bag + bristles + sticks to generate novel combination, and his thought behind his idea generated was written as ‘It is a plastic bag with bristles inside, which is attached to a pad, a stick is used for hitting to clean the clothes’ as shown in Fig. 4.7.

The student tried to use the sticks for beating clothes inside the plastic pouch and to squeeze the plastic pouch from where the water flows out of the bag through outlet at a corner as shown in Fig. 4.7. Another idea generated is by combining hand gloves with bristles. In test T2, the student changed his approach of solving problem from problem focus to solution focus, and the ideas generated are non-obvious and workable compared to the same student who solved same problem without external support condition as shown in Fig. 4.4.

4.5 Closing Remarks on Implications for Design Education in India

In test T1 result, the students’ thinking indicates to generate ideas resembling to machine kind of objects associated with bucket which are more toward technical side, instead of focusing on designing a tool. Overall, the students’ responses for test T1 are all disjointed and not focused on the actual problem, that is designing a tool, which assists the process of washing clothes. This may be due to the problem which is ill-defined for the students at the initial stage of problem solving, and students tried to employ problem-focused approach, which affects largely on creativity.

On the contrary, in test T2, the students’ thinking of using bucket has been reduced drastically compared to test T1, and nearly fifty percent of students’ generated ideas are in relation to combine hand gloves with bristle, irrespective of their background. The students tried to generate multiple ideas by combining multiple cues. This shows that there is a significant change on the approach of problem solving among the students using combinatorial tools. One important comparison between approach students adopted while solving creative problem under two different conditions is different; under condition 1, students’ approach is linear, and under condition 2, the students adopt nonlinear approach as shown in Fig. 4.8. Students adopted two loops as depicted in flowchart. The argument is also supported where the attempt was made to intervene in the model of Amabile as depicted in Fig. 4.1. This makes students divert from linear approach of creative problem solving.

Jones and Rodgers raised the following questions to design tutors [8].

(1) How design teachers conceptualized creativity? (2) Whether design tutors see creativity as important and/or valuable in design education? (3) Whether design teachers think they possess creativity themselves and whether it is important that

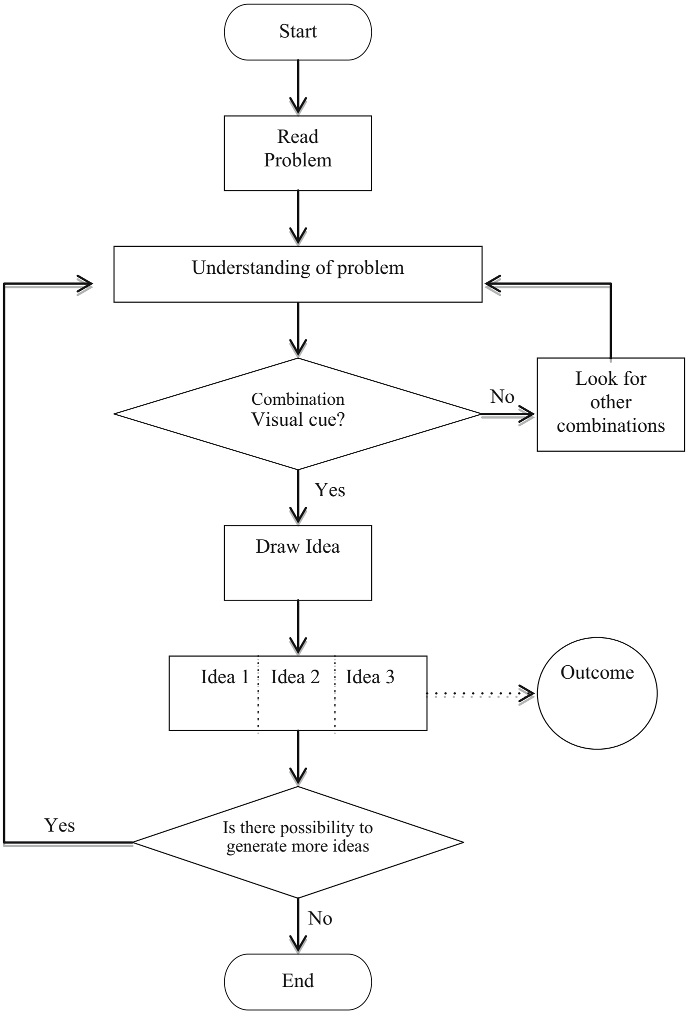

Fig. 4.8 Flowchart of students' nonlinear approach while solving problem under condition of idea wheel

they do? (4) Whether design tutors would like to know more about creativity and improve their teaching for creativity?

Perhaps such questions in relation to teaching creativity have rarely been addressed in design education in India. Will this in turn improve the performance of students where the courses focus on awareness development, creative problem solving, synectics tools, and creative analysis process? Assuming that design teachers are aware of creativity and creativity tools but how to include in design curriculum and at what level are question that remains unresolved till now.

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Chapter 5
Discovering Strategies for Design of Purposeful Games—A Preliminary Study

Sandeep Athavale and Girish Dalvi

Abstract Purposeful games are games having a purpose such as education, in addition to entertainment. Though there has been significant interest and research in educational game design recently, the design of games that seamlessly deliver engagement and learning is still a challenge. Games with endogenous design are likely to balance engagement and learning. Endogenous design implies that the gameplay emerges from the educational content. We, therefore, focus on discovering strategies for the endogenous design in our research. As part of preliminary study, we conduct an exploratory workshop as well as pilot studies using protocol analysis to understand strategies that designers use. The main contribution of this paper is an early report on strategies for the endogenous design of educational games. We find three broad themes of strategies—(a) the process and the steps, (b) the extraction of 'gameable' elements from the content, and (c) the translation to game elements. This research is a stepping-stone toward deeper research into endogenous design of educational games.

5.1 Introduction

Design of educational games is challenging as it entails balancing engagement with learning (the purpose of the game). Educational Games become effective when the act of playing and act of learning are the same. This is possible when the act of playing is derived from the educational content. Such a design where the gameplay is generated from within the educational content is called endogenous design [1]. In such design, the content and gameplay are interwoven and cannot be easily separated. An example of endogenous design is a game 'Entangle' designed by the

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authors for learning basic shapes in geometry. In this game, the 'play' is about placing sticks on a grid board and claiming the scores based on shapes formed. When the students claim the score using the shape tokens (printed with shape names) from the bank, the 'learning' is inherent to the play.

On the other end are exogenous designs where the gameplay is superimposed on the content. An example of exogenous design is a math calculation game where the player has to race a car to destination. The math problems come in between as hurdles and need to be solved. Here, the act of playing the race and the act of learning by solving problems are separable. Such games may neither be effective in delivering learning nor fun.

Designers, especially novices, seek guidance on designing endogenous games and can do well if they were acquainted with strategies for the same. Deen [2] suggests that designers should use the endogenous design for educational games, i.e., search for 'restructureable elements' in the learning content, and create a gameplay that is cohesive with the content. However, the strategies to arrive at such design are not forthcoming. 'Design strategies' is generally an understudied subject in the context of educational game design, and hence, designers create exogenous designs by default.

Design strategies here imply specific methods, working principles, and steps in the design process [3]. Through our larger research, we aim to discover strategies for endogenous design. We are interested in knowing the strategies that designers use or can use for (a) identifying the gameable elements in the content/context of the problem space and (b) translating or relating the identified elements to the game elements. We presently focus on educational games based on middle school syllabus. In this paper, we specifically focus on preliminary studies to discover strategies.

Design knowledge can be generated through the study of design practice or artifacts (games already designed), or the nature (ability) of designers [4]. We plan to study the design practice (designers in action) using protocol analysis method. Protocol analysis is better suited for investigating tactics and strategies employed by designers [5, 6]. However, protocol analysis demands significant effort from the participant and researcher and hence adequate preparation to ensure that the effort is not wasted. The preparation includes deciding appropriate research design, selecting appropriate participants, and deciding design tasks that are feasible as well as equitable. One of the ways for preparation is to conduct preliminary studies.

We conduct preliminary studies for the same reason. Interestingly, the preliminary studies not only help in the validation of our data collection method but also help us get a head start into knowing the strategies that designers use to translate a topic into a game. In this paper, we report the strategies discovered from the preliminary studies. The main studies will be conducted post these and reported separately.

In the further sections, we describe the related work and gaps, the methodology to conduct the preliminary studies, and the strategies we discovered through the analysis of the generated data.

5.2 Related Work

Educational game design research has generated significant interest in the last couple of decades. The literature is specifically rich in two areas—first, in proposing models for mapping of learning pedagogies and game design, and second, in the evaluation of games toward achieving learning outcomes.

The mapping models provide a macro-level understanding of game design for learning purposes. For example, Amory [7] proposes game object model for designing serious games. This model gives an idea about placing appropriate game elements within the educational content. Due to the abstract nature of the model, it is quite possible that games designed for learning geometry or history may have exact similar features. The game design is not informed by the content but the pedagogy. Building upon Amory's work and using Blooms Taxonomy, Arnab et al. [8] propose a Learning Mechanic to Game Mechanics (LM-GM) mapping model. While the model provides an idea about mapping pedagogic objectives to game mechanics (such as how to map evaluation in learning with challenges and points in games), it is not attempting to provide guidance on strategies for designing specific gameplay for the specific topic. Prensky [9] has proposed a mapping of possible game styles with different types of learning content. For example, he indicates that flash card-type games are better suited for the content having factual nature because the learning activities are typically memorization and drill. Similarly, he indicates that for behavioral training games, role play-type games are better suited. Though he provides some insight into high-level strategy (about the choice of type of game) for designers, he does not provide micro-guidance about how to design games by choosing the elements from the content.

While the literature on mapping evaluation is growing, the focus on synthesis of games is still insignificant. Bellotti et al. [10], through their meta-analysis, find that despite the abundance of literature on serious games, only a few papers provide specific strategies through which a topic is 'translated' into a game.

One of such few attempts is by Hall et al. [11], who present a serious game design technique for mapping instructional objectives to core-gameplay. Their framework proposes an inquiry-based approach for the serious game designer. The designer needs to ask key questions as a means of clearly connecting instructional objectives to core-gameplay. While this is a useful step in providing a specific checklist to the designers, it still does not provide an idea about the strategies to translate the content to gameplay.

Our multi-stage research aims to work through this gap and identify design strategies for aiding educational game designers.

5.3 Methodology

The research objective of the preliminary study is to get an early understanding of the nature of design strategies as well as the suitability of the method for generating intended data. This will help us fine-tune the main studies, which we will conduct subsequently.

Our research is predominantly qualitative in nature. Understanding the complexity involved in human cognition such as use of strategies in design practice demands rich qualitative data about fewer individuals rather than quantitative data about populations [12]. Rich qualitative data can be uncovered through 'in situ' analysis of design activities. Protocol analysis is a predominant method of discovering strategies through in situ studies, wherein the design decisions are recorded.

Though protocol studies have not been applied to specifically study game design, it has been employed to understand the design strategies, tactics, ideas, rationale during an engineering design process, or architectural practice [6, 13, 14]. Since we plan to understand the use of strategies, we believe the specific design task does not matter as far as the method is concerned. Hence, we apply to protocol analysis to in our study. In situ studies, however, are costly and require higher effort in preparation and analysis. Therefore, generally fewer participants are studied.

Alternatively, use of post facto analysis can be less effort intensive. However, post facto is better suited for the study of outcomes rather than the process. In the post facto analysis, the insights are generated based on the design outcomes and the interviews of designers. However, backtracking to designers is not easy.

The twelve main studies of our research (not reported in this paper) to discover strategies will be conducted using protocol analysis. Since protocol studies are effort intensive, preliminary studies can help check the appropriateness of method and determine whether we are able to discover strategies of our interest. This paper focuses on preliminary studies. In preliminary studies, we conduct (a) an exploratory study at a game ideation workshop to get the understanding across breadth of topics and (b) two pilot studies using protocol analysis to understand the depth of design strategies in specific topics. These studies are adequate to get a sense of direction and do fine-tuning before main studies and we do not expect the results to be conclusive.

As part of preparation for the studies, we decide the design tasks. The design tasks are selected to represent different types of content. The content type classification is done using the Krathwohl matrix [15]. We expect that the design strategies will be related to the type of content. This is unsurprising because the instructional strategies depend on the type of content and learning objectives [16]. The topics for the exploratory studies were chosen from a short survey of schoolteachers who listed either difficult or boring topics where games could help them. The topics for pilot studies were chosen from outside the school syllabus but were of practical importance in current social context. In both cases, the topics were chosen such that the participants do not need specific expertise. Participants were also given time to assimilate and understand the topic at the beginning of the session.

We discuss the studies further.

5.3.1 Data Collection Through Exploratory Study in a Design Workshop

We conducted a half-day workshop at a design school in Mumbai (Fig. 5.1) for the exploratory study. Eight students, who had undergone game design course earlier, were invited to participate. We gave them design briefs and requested them to generate game ideas on educational topics, preferably with endogenous design. We also invited a game design expert to help evaluate the ideas independently using evaluation rubrics that we developed. We noted the strategies used. We discuss the findings in the results section.

5.3.2 Data Collection Using Protocol Analysis

We conducted two pilot studies using protocol analysis. We conducted two studies to overcome any bias due to the selection of particular participant or topic. Each pilot study had one participant. Each participant was given a task to design a game in a 3-h session. The participants were requested to strive for endogenous design. Since we used concurrent protocol analysis, participants were requested to think aloud while designing. Their activities were audio-video recorded. Additionally, participants were requested to give a retrospective account of the activities after the session has been completed. Data from protocol studies were analyzed using coding techniques.

Fig. 5.1 Data collection session at exploratory workshop in design school

5.4 Results and Analysis

5.4.1 Observations from the Workshop

The observations from the workshop are organized in Table 5.1.

The participants were given topics from different types of content. In the observation table, we listed the type of content for the topic assigned to the participant (topic indicated in column A and content type in B). Observations noted during the workshop are recorded in subsequent columns. The column C indicates the prominent properties of the content observed by the participants and D indicates the role of human in the context (what people do with the elements in the content, their goals, and behaviors).

Further, column E indicates the contest candidates (elements that can have some tension or conflict between them), F the elements selected by participants for creating gameplay, and G the proposed gameplay. Though we collected data on 18 topics, we present a sample in the table for brevity.

We expect that the game design elements—especially the mechanics—will vary based on different types of content. We discuss a couple of observations on that; however, we have not yet done that specific analysis in detail and hence may not be able to discuss that correlation in the current paper.

Based on the data collected from the workshop, we could discover following guidance on strategies.

a. Designers look for 'gameable' elements from the content. This includes surfing through the various elements of the content, noting the structures and properties of elements (including physical properties, spatial layouts, temporal movements, etc.).
b. Designers look for the role of humans in the context—identifying the goals and behaviors of people in the context. For example, if the topic is force—the human goal can be 'move objects' and the behavior could be move own objects efficiently and block others. This step is about knowing what players could do in the context, and what actions they can perform. Designers also study the interactions between people as well as interactions between people and objects.
c. Designers look for some phenomenon for a contest. This involves finding which elements/properties can be pitted against each other, which behaviors oppose each other, etc.
d. Designers select a suitable gameplay not only based on the information gathered but also their knowledge of existing gameplay and game mechanics.
e. Designers also chose some amount of fantasy (though not indicated in the table). For example, in the geography game, some rocks were given magical properties (which do not exist in the real world).
f. The type of content has a bearing on the type of gameplay. For example, the topic on fundamental rights is translated as a game of challenging situations which the player overcomes using the rights cards. The factual content type drives the choice of this gameplay (use of cards that deal with information).

Table 5.1 Observations from pilot studies

	A Topic and type of content	B Type of content	C Properties derived from the content	D Humans in the context		E Contest candidates	F Selected elements	G Gameplay
				Goals	Behaviors			
1	Rocks and soil in geography grade 7	Factual	Rocks can be formed and broken	Use rocks and soils for various purposes (agriculture, construction, etc.)	Humans use rocks and soils for various purposes	Build versus break	Use of properties structure spatial	Players collect rocks and build their own castles and destroy opponents
2	Force in physics grade 9	Conceptual	Force creates motion force stops motion	Use force to move objects	Humans use force to do work	Contest-block opponent while pushing own tokens	Use of properties, objects, movement	Players have to use force on a grid to move tokens to other end
3	Reflection of light in physics grade 8	Conceptual	Objects that reflect light, e.g., mirrors, that converge/diverge light (lenses), darkness, shadows	See something, hide something		Pass light rights, block light rays	Use of properties, objects, movement	Players have to use principles of ray of light and the mirrors etc. to lake ray to other end
4	Atoms, molecules, reactions in chemistry grade 8	Conceptual, factual, procedural	Atoms can combine to form molecules, molecules can participate in reactions	Combine elements	Humans use specific compounds for specific uses	Make or break compounds	Use of structure	Players have to collect pieces from the bank to create own structure and block opponents
5	Fundamental rights in civics grade 7	Factual	Rights are permanent rights come with responsibilities	Use rights for better living	Misuse, infringement, lack of awareness of rights	Crime, suppression versus rights responsibility versus rights	Simulation—role play decision making	Players have to use rights to overcome situations

g. In most cases, we find that designers have been able to create an endogenous design. For example, in the game on molecules and reactions, players have to assemble appropriate atoms with holes and bulges to form molecules. The act of playing is thus same as the act of learning. However, in the fundamental rights game, only some elements of design were endogenous—for example, 'rights cannot be destroyed'. The gameplay was otherwise exogenous—with learning situations embedded in a racing game. However, this cannot confirm that endogenous design was not possible for the particular topic.

5.4.2 *Observations from the Pilot Studies*

The summary data from the two pilot studies, conducted using protocol analysis, are presented in Table 5.2. Participant 1 is a female aged 38 and 2 is a male aged 26.

In order to give an idea of the kind of concepts that participants generate, we have included the schema of concept on traffic awareness game (Fig. 5.2) generated by participant P1 in the protocol analysis session.

The game is a multiplayer game where the players have to race through city to reach a destination. On the way, they can choose to follow rules or break them and face consequences accordingly. The translation from content to game in this case is mostly simulation of real world with introduction of some fantasy elements.

The analysis of the pilot studies informs us of three themes of design strategies. These are (a) the longitudinal aspect of game design, (b) the elements scanned from

Table 5.2 Observations from workshop

Pilot study	1	2
Participant	P1 (F 38)	P2 (M 26)
Design task	Safe driving and traffic awareness	Awareness of digital banking
Audience	Teenagers	Financially challenged
Design duration	2 h	3.5 h
Gameplay	Two teams race to the destination through city traffic. Players encounter traffic, have to follow or break rules	Traders exchange goods and transact using electronic currency in a village economy
Elements extracted from the content/contents	Actors (riders), Objects (vehicles), layout (routes), events (accidents), basic phenomenon (movement), behaviors (risk underestimation, ignorance)	Actors (sellers, buyers), transactions (buying/selling), behaviors (lack of trust)
Key element translated to gameplay	Movement	Trading of goods and exchange of currency

Fig. 5.2 Traffic awareness game concept generated by P1

the content, and (c) translation to game elements. While the themes of ‘scanning of content space’ and ‘translation strategies’ were also observed in the exploratory studies, the longitudinal aspects of the ‘design process’ could be gathered only through protocol studies.

In the ‘design process’ theme, we observed the designer activities such as seeking, generating, evaluating, and discarding/selecting alternative solutions. This is similar to the micro-strategies by Gero [17]. The temporal analysis of these activities indicates multiple intertwined loops, supporting the notion of iterative design.

For generating ideas, the participant referred to the prior experience of games in the respective domains (of traffic awareness or digital financial transactions) as well as games in general. This observation is consistent with Hagen’s claim [18].

Due to the longitudinal studies, we could also figure out the specific points where the participant struggled. For example in designing traffic awareness game, the participant struggled to build opposition mechanic or generate non-compliant behaviors. The participant resolved it through a system of payoffs between risk-rewards-penalties. We also observed the rationale for keeping some ideas and discarding other—for example, P2 chose ‘trading of produce’ instead of abstract transactions keeping the intended audience in mind. We could also observe that the participant P1 was seeking elements of fun that could fit in with the purpose. For example, she also controlled the racing ahead of one team by creating mandatory waiting points (such as river crossing by a jetty).

In the second theme, ‘scanning and extracting’ elements of interest from the content, we find similarities in the designer approach with the observations in the exploratory workshop (Table 5.1). The participants in protocol studies also looked for the properties of the content/context, the goals, and behaviors of people in those contexts. The scanning of problem space may appear similar to function-behavior-structure (FBS) classification by Gero [17]; however, we have not attempted mapping our findings with FBS yet.

In the 'translation' theme, we expected the translation from content to the game, to consist of two parts, namely (a) simulated representation of content in the form of layout, traffic rules, constraints, and (b) twisted or metaphorical representation or fantasy. One traffic game participant chose simulation whereas in digital transactions game it was part simulation and part fantasy world. Further research can confirm if this is due to the type of content or participants limitations.

The pilot studies provided strategy guidance such as

a. Designers scan the problem space for specific properties that lend themselves to gameplay generation (found in the exploratory workshop as well)
b. Designers perform trial and error with multiple gameplay possibilities in relation to scanned properties
c. Designers look for support for design decisions from the elements of the content
d. Creating opposition mechanics is challenging. Designers use payoffs and use fantasy to create the opposition to reality. This may affect the intended learning if not handled appropriately
e. As designers are not able to come with endogenous design in every case, a standard fallback mechanic (such as race) is used.

5.4.3 Discussion

The goal of preliminary studies has been achieved as it helped us in (a) getting a sense of kind of strategies we can discover and (b) validating whether the chosen methodology helps us generate expected data.

The strategies that we discovered in preliminary studies help us understand that we are indeed generating new knowledge, which hitherto has not been explicitly captured. Design strategies for educational games and especially for endogenous design have not been discussed in literature. Further, the specific nature of strategies, e.g., how to extract elements of interest from the content, will be a useful augmentation from the high-level mapping frameworks currently available in this space.

Once we complete the planned main studies, we need to compile the strategies in usable form and shape. We also need to do ecological validation to understand how these strategies apply in the field. While the further planned studies will make the findings generalizable within the chosen segment of educational topics, these may not be generalizable beyond that.

5.5 Conclusion, Limitations, and Future Work

The preliminary studies provided us with initial but useful insights on strategies for endogenous design. While the exploratory workshop helped us get an idea about the breadth, strategies for various contents, the pilot studies helped us understand the deeper insight into the design process for a specific topic.

The nature of preliminary studies signifies that we treat these results as early indicators and not conclusions. We need further studies for reasonable coverage of participants as well as topics. We will study the relation between strategies and the design outcomes they lead to, such as endogenous nature (cohesion between content and gameplay), novelty, engagement, and learning effectiveness. We will also study the correlation between the type of content and the strategies. We plan to present the discovered strategies in the form of a usable framework for game designers, especially for novices, in order to design effective educational games.

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Chapter 6
A Thought on Models of Design Processes: Abstraction, Representation and Reality

Paul Varghese

Abstract Issues of epistemology/knowledge representation and how it functions in design is explored. Some categorisation methods are looked at, and how it can be used is studied. Definitional problems of 'design' are viewed, and an elementary classificatory system is proposed. One extends the argument to tackle issues of representation, and ways to rationalise the processes. Representational models, mostly logical, computational or cognitive, are explored.

6.1 Introduction

This conceptual paper critiques models of the knowledge and design processes—in the transition and interactivity from abstract thought, through representational mediums (real/virtual), to a possible final constructed reality. Use of such processes is seen every day in design, yet the design community struggles to come up with codification of these into categories or methodologies, which could serve as reasonable tools for design. The reason probably is because these processes are often personal or subjective, and not often replicated.

The paper first compares a few epistemological models of knowledge representation, which is extended to see how design could fit in. The design process is compared against frameworks of knowledge representation and development, which could help academics and researchers frame their understanding of the process while it proceeds in the foreground. Three models used for comparison are—the '*Three Worlds*' framework proposed by Popper [1], the one proposed by Mouton [2] also called a *Three Worlds* framework and the current paper's one used as a generic. Though Popper's and Mouton's frameworks are primarily meant to look at epistemological information flows, they could be adapted for understanding the design process. One explores the manner in which design could be categorised, and in what way these categories could be used to understand the world of design processes.

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6.2 Cutting up the World

6.2.1 World Views and Knowledge Representation

Popper's [1] view, he states, is different from the worlds of *monists*, who believe that everything in the universe is made up of just differing types of matter, or of the *dualists* who accept that the cosmos is composed of physical entities and some abstract non-matter. In contrast, his '*Three Worlds*' theory defines the total environment made up of three worlds (say *W*1, *W*2 and *W*3), comprising of existing entities (*W*1), the products of thought (*W*2) and the result of interplay of thought and the physical entities (*W*3).

Popper suffices it to think that this pretty much defines all that can be thought of in the world. Popper's *three-world* ontology consists of all *spatio-temporal elements* of real-world objects, living or non-living that exists (*W*1); *subjective knowledge* and abstract elements of that of minds, thoughts, perceptions, intentionality or mental states (*W*2); and *objective knowledge* that of unembodied or embodied entities on which *W*2 has acted—(*W*3). *W*2 would encompass those abstract elements of perceptions, ideas, conscious thoughts, etc., that are often the result of contemplation of *W*1; *W*3 is the result of processes of rumination on *W*2, and which has been verified and is the result of the development such as language, recorded thought, art, and artefacts. Popper's definition, however, is often unclear and complicated, in distinguishing between the products of thought and the result of natural development (*W*3/*W*1), but not probably for Popper himself; a matter of perception. In a manner, wouldn't the objects developed in *W*3 later become part of *W*1?; especially when one considers that objects of art, architecture, etc., become part of the existent worlds, which in turn is also reflected upon or generates thought which becomes part of *W*2; the loop is in a continuum. This cycle of element identification requires significant distinguishing criteria to make the categorisation relevant. While complex, one can see that the process of classification has certain similarities with the processes of design to warrant further reflection. A preliminary look at existing objects does not on its own betray its position in his scheme, but could, upon detailed analysis; hence, the complexity as well as the dynamic nature of the classification needs appreciation.

Mouton's [2] model of '*three worlds*' probably was inspired by Popper's classification and has similarities; it sequentially lists that of the real world of everyday objects (let us say, W_m1), the world of science (W_m2), and the world of *metascience* (W_m3). These essentially represent a way to look at a physical and an epistemological classification. Mouton extends the definition to distinguish them into his three worlds, which seems clearer, and one can distinguish the worlds of existent objects, of everyday articles and substances (W_m1); based on the first, one generates scientific thoughts and knowledge, and ideas of epistemological interest (W_m2); on further refinement or distillation, one is able to develop profound principles of the world which could be termed as *metascience* (W_m3); W_m3 would be the deeper ideas of philosophy, research methodologies, ethics or similar.

The importance of Mouton's classification is that it helps evolve hierarchies of knowledge, both developed or generated, and which would be of use to the academic, in developing research ideas and directions. Eventually, one develops principles that philosophise and drive the relationship between the world of objects, the world of science and the world of ideas. In terms of design, one can see that such classification schemes can help identify strata or an ordering of principles which would be useful in laying out the pedagogical field for learners and in academia. One could even go to the extent of saying that developing hierarchies of representational schemes could encompass the idea of everyday layouts, details then taken to the next level of design ideas, standards and conventions; and eventually leading to that of higher design axioms or canons, if relevant.

At a mundane level, one could parallel the hierarchy to that of raw **d**ata, **i**nformation, **k**nowledge and finally to **w**isdom—each of these signifying levels of refinement before it makes itself useful to the perceiver; this is also known as the *DIKW* pyramid, attributed to Ackoff [3].

6.2.2 Knowledge and Design

For design, a differing classificatory system is explored, which takes its inspiration from the systems described in ontological research. Popper's is extended by Mouton, also using similar terminology, but clarifying the purpose of each world into more distinct entities. There is value in these schemes despite their drawbacks. The above classification systems work quite well in the epistemological world of knowledge and its representation.

Viewed through the lens of Popper's theory of '3-*worlds*', and its interpretation by Mouton [2], for design talks about the role of each of the phenomena in the real world, i.e., abstract thoughts in a person's head, representations such as sketches or drawings, to final constructions in factories or on site. The designer is mostly involved in the representational phase, where thoughts and ideas are converted into the representational form of drawings or visualisation models using modern computational technology.

The world of epistemology—knowledge and its representation, and the world of design, as we know it—is different but related. Design takes and manipulates both knowledge and its representation into differing forms, depending on the requirements or needs of the hour; knowledge of the objects or entities is worked upon, along with its properties, to suit the needs of society, or sections of it. This change could be as done earlier, or in novel ways—invoking creativity for newer uses, according to Varghese [4]. Design itself may not engender creativity, but creativity implies the use of something that did not exist earlier, possibly the use of older methods or instruments in novel ways.

This transition of ideas from random thoughts, through doodles or sketches, to a final product is hazy, and that is neither standardised nor properly documented, except in parts. The effort necessary to capture the processes involved is fragmented within the academic community, following schools of thought from diverse bases. This is since the approaches taken by different players are individual, possibly with certain schools/corporates following respective methodologies. In general, what could be said is that the process starts out abstractly, and sometimes ends as a tangible product.

The work of Gero and Kannengiesser [5] seems it has correspondences with the current basis. Their viewpoint of 'situatedness', disregarding the F-B-S framework, seems to have parallels with Popper's [1], and the design paradigm; their separation of the abstraction approach into the (1) *external world* say *W*, (2) the *interpreted world*, say *I* and (3) the *expected world*, say *D*, corresponds with the real world that the design problem has to be situated, the interpreted world *I* of how both the designer, or a viewer, who are individuals and who might never have the same interpretation of the and the expected abstract world *D* of intentions that a designer begins with.

The designer transits between these three worlds in coming up with a solution. She has to begin with the expected world *D*, where the intents, thoughts, concepts, ideas and possible solutions are explored; in the interpreted world *I*, the designer tries to fit between the real-world *W* solutions and the expected world *D*—where she has to interpret both from *D* as well as *W* in finding solutions. Finally, in getting a solution, it has to be built in the real-world *W* using tangible elements, sitting in a real site or real-world materials whatever they be, existing or manufactured; the world of design switches between these three.

The field of cognition and cognitive science is nascent, and not comprehensive enough today to gauge the breadth of possibilities in design. This does not mean that no effort has been put to comprehend this. It has been a quest of humankind and philosophers from Plato to the *rishi*s in the Himalayas, to understand the workings of the human mind, which possibly also holds wider answers to that of the universe.

6.2.3 Issues in the Definition and Use of 'Design'

The paper suggests a classification system that could make things clearer for designers; it would seem that designers suffer from a limited vocabulary. Designers use the word shifting between the various aspects, meaning—of the idea, the representation as well as the artefact; adding to the confusion, the word is used both as a *noun* and a *verb*, meaning that the *process* as well as the *product* is referred to similarly. While the individual using it seems to know quite precisely what she means, it is the listener or reader that is left unclear. One expects that parts of the process would have a differing nomenclature for all of these which are collectively come under the appellation of 'design'. The legend that the Eskimos/Intuit have fifty different words for snow or ice is generally known to be untrue (however, it would be various combinations of half a dozen or so which finally add up to several dozens). Designers need to have different modes to distinguish and describe what they are doing and how they are doing it.

The paper's preliminary scheme, in terms of design, is interpreted as the process existing in the worlds of abstraction/conceptualisation (*D*1), the representational stage (*D*2) and finally the constructed stage (*D*3), used in Varghese [4].

Part of this classification can be seen as a parallel in Eastern (both Hindu and Buddhist) philosophy, where one classification is distinguished as *mind*, *speech* and *action*, even though the intent is not related to design. This categorisation, strangely enough, is one where one cannot fault the distinctions. The sense of the three entities is much less confusion in its characteristics. As mentioned, the modern design equivalents of the stated entities would be *idea* (or *ideation*), *representations* and lastly the *artefact*, which would be the final built-form.

The paper's *schema* for a distinction within design especially could be compared with the ideas of Popper [1] and Mouton [2], where the existence or physicality of the entities becomes the distinguishing element. In this, the philosophical existence of each could be separated just as is described, to the components of mind (*manasa*—मनसा), speech representation (*vaca*—वाचा) and the actional or artifactual representation (*karmana*—कर्मणा) in the *Sanskritic* nomenclature of Indian philosophy, which could help to differentiate them in the developmental stages. The equivalents in Japanese philosophy [6] in the *Sokushin Jobutsu* in the Shingon tradition of Japanese Buddhism—also called 'the three mysteries'; the mystery of the mind called *I mitsu*, the mystery of speech—*Ku-mitsu* and the mystery of action—*Shin-mitsu*, listed in reverse from traditional usage; the origins of these beliefs and practices possibly came through China. This classification helps differentiate the development between mental and physical stages. This could for comparison be paralleled to the stages of *idea/ideation*, *representation/drawing/model* and that of the *constructed reality,* as in Table 6.1.

Distinctness in the terminology helps differentiate between the stages of thought, representation and constructed entity. Design stages can be given the nomenclature as *D*1, *D*2 and *D*3, where $D1 \rightarrow D2 \rightarrow D3$ is the normal flow of process. In the sense of design pedagogy, this process is taught as well as followed, in that the initial stages *D*1 and *D*2 are given emphasis; this is true of civil engineering,

Table 6.1 Stage-wise equivalents from Indian, Japanese Buddhist philosophies and Design Representational stages

Indian philosophy	Japanese Buddhism (*Sokushin Jobutsu*) *in the Shingon Tradition* The Three Mysteries (*Sanmitsu*)	Design representations
Mind/*Thought* मनसा	The mystery of the mind (*I mitsu*)	Idea (*D*1)
Speech/*Word* वाचा	The mystery of? speech (*Ku-mitsu*)	Representation (*D*2)
Action/*Deed* कर्मणा	The mystery of? action (*Shin-mitsu*)	Built-form/artefact (*D*3)

architecture, or product design. Trade schools which teach the practical side of the process are more involved with the $D2 \rightarrow D3$ period. The stage of $D3$ is the responsibility of contractors or fabricators, who read the $D2$ drawings, specifications or construction documents to be converted to $D3$.

6.2.4 The Stages of Design

The differing stages of the process that is gone through could be classified and nomenclature tagged. At the ideation stage, one talks about concepts, brainstorming, thoughts, requirements, needs, etc., that come under the category of ideas, as $D1$. One could sort documents, such as a formal list of requirements, a design brief or to the final tender documents inclusive classified under $D2$, the representational stage. When one considers the stage of real construction, fabrication in the factory, for assembly, or of actual erection at site, it could be categorised as $D3$.

One could contend that there would be intermediate stages, or that it is not quite clear-cut—but that would be a misconception. Intermediate stages would belong in one category or the other, sometimes even within a single operation. The idea of prototyping, or of *3D* printing, even though it would be a single operation, would function in the phase joining $D2$ and $D3$; the stage goes from a representation to a final product. As an alternate, one could create a category as $D2 \rightarrow 3$, *or* $(D_{2\rightarrow 3})$. One could reason that in certain categories of work such as painting or sculpture, $D2$ and $D3$ are the same; this too can be debated on both sides, or one could even tentatively list it as *ambiguous*, which is not a category that is unknown in classification schemes; the end result is as valid as the proposed plan of action.

6.2.5 D2, the Stage of Representation

In engineering design, Wynn and Clarkson [7] list an overview of the literature mostly from engineering design; they have divided up the literature into a framework by scope and by type; by scope they have divided methods into *micro*-, *meso*- and *macro*-level, depending on the tasks and the contexts; in type, they have divided up the studies into procedural, analytical, abstract and MS/OR (mathematical models of management science or operations research). The categorisation is explained in the form of a spiral which rotates outwards and theoretically possibly takes the form from the organising framework of Evans [8] in 1959, used for ship design along 16 dimensions. Such a spiral model has become popular for depicting the design process, also being used in areas such as software engineering [9]. Engineering problems sometimes also can be consolidated from a kit-of-parts approach, where it is the assembly of components/assemblies (or sub-components/sub-assemblies) for solving a design problem.

A counter to this is that certain problem-solving methods, especially within an engineering context is that often problem-solving and design are quite linear, and can be solved in a sequential manner where the beginning and end conditions are known.

However, it must be emphasised that often problem-solving is not so easy, especially when the process or the final product is not well known or understood. Sometimes these are listed as being 'wicked', where solutions are difficult or even non-existent. This is the case where the process is unstructured or has to be built from fundamental principles. This is often in the realm of planning or within the social sciences [10].

In many areas of design, where the technology, the process or the final form of end-product is not known, then many of the processes need to be almost invented from scratch. Thus, the factor of novelty and innovation comes into play, where technologies need to be invented for each need. Sometimes, only an initial set of requirements is the starting point, and then the specifications have to be built up, and the processes and methods need to be developed.

In many instances, problem-solving does not grow from solving micro-level issues to macro-level ones; often, solutions and sub-solutions are found at differing stages of the process, and then stitched together, with some in-between sub-assembles holding it all in place without breaking down. These can be seen as sub-assemblies at the *micro*-, *meso*- or *macro*-levels [7].

Much of the attention as designers is taken for the $D2$ stage, sometimes at the $[D1 \rightarrow D2]$ stage, depending on the work involved. As academics, the $[D1 \rightarrow D2]$ stage is given importance; in the early stages, this involved strenuous effort in learning the discipline to develop skills depending on the art or trade involved.

The $D2$ plane is affected in the design office in practice, or the design studio in academic settings; this is true whether the representational process was from the ateliers of artists during the Middle Ages, current structural design in academics or practice, or the experimentation stages in a modelling laboratory. To an extent, a proportion of time is spent at this stage in academia, in preparation for the move to actual practice. One could say that the idea of 'practice makes perfect', at the pedagogical stage (पूर्णता, *purnatha;* 完璧, *kanpeki*), indeed at each stage was the ideal, in all the stages; however, it can be emphasised that the idea of perfection in $D1$ and $D2$ are the least expensive and the preferred option, leading to perfection in $D3$. Experimentation at the $D3$ stage would be expensive in terms of time, money or energy, as also in recall, reparation or compensation.

Within the representational scheme of $D2$, there are several subdivisions. The twentieth century has thrown up fresher models of representation $D2$, primary among them is the phase of computational representation, which is significant for the impact it has brought about in terms of time savings, as well as the rate at which the cycle of ideas to representation goes through. The idea of computational representation is of significant interest and research. One could term it as $D2_V$, for 'virtual representation'; with the coming of computational methods, the development of design software has become commonplace enough that today not much design proceeds without it, or that both pedagogy and practice are insistent on such skills for the modern designer.

It could be mentioned that the contemporary equivalent also needs to be included in the model. Representation itself is a large field of study; for one's purposes, one needs to include the virtual equivalent model such as the computer representation (or virtual reality). The virtual representation has now been extended to the idea of dynamic representation which can also be deliberated as a study in itself. Clipson [11] has a definitional scheme shaping the components of simulation as (i) *iconic,* (ii) *analogue,* (iii) *operational* and (iv) *mathematical* models; these are classified under their differing properties of use, components, properties, etc.

6.3 Logical Models of Design and Representation

6.3.1 Logical Models

Models had been suggested since the 1950s to describe design as cycles of *analysis* and *synthesis*; these models from Design Methods Group [12] were further extended to include the part of *evaluation*, as per Lawson [13]. The use of including it as made up of pure *deduction* and *induction* has been distributed to include the role of Peirce's [14] interpretation to include *abduction*; March [15] extends it to include cycles of the three, despite the differences of terminology. Models of the process of design could be interpreted through these processes of deductive, inductive and abductive logic in the conceptions of Peirce [14], March, etc.; March [15] is of the view that abduction utilises creativity, which is what makes design different from science. Magnani [16] follows Peirce's [14] thought in stating that the generation of a scientific discovery itself requires abductive reasoning.

The issue of logical models of representation is not new, and the idea of capturing the design process in succinct manners has been analysed earlier. Generic models of design have been put forward, and such models have got parts of it, but it has proved difficult to capture all of it in a single entity.

Varghese [4] has suggested that the partial reason for this is because of the genericity of the word itself—'design' serves to describe both the *process* and the *product*, as a *verb* and as a *noun*; this makes it a step more confusing.

The issue of how one goes about designing needs probably a significant amount of research. Is there a definite or different methodologies to it, are they equally valid, and similar questions need to be looked at in great detail to understand the approaches adopted by designers or non-designers.

Problem-solving is a part of the process of design, but does it end there? These kind of questions are asked by technical as well as non-technical personnel alike. Is design purely a creative process which has no link to the utility of the product, except an aesthetic function is a question that an artist would answer in the affirmative.

6.3.2 The Craftsman's Model

As an interesting digression from the main argument, the stage of representation $D2$ is not always necessary in some cases, as within a *craftsman's* frame of reference; one can look at this differing possibility of practice, for distinctness called a c*raftsman's model*, where artefacts are built by artisans; here the craftsman builds an artefact without the intermediary stage of representation; the transition is seemingly [$D1 \rightarrow D3 \quad (-\ D2)$], without the $D2$ in between, or that $D1$ and $D2$ are combined [$D_{1\rightarrow 2} \rightarrow D3$]. The craftsman is familiar enough with the fabrication process that a representation is not often required—the craftsman goes from the idea to the artefact without a representation. One could say that the person is familiar with the process that a description of the final requirement is sufficient to comprehend or generate the final artefact. If the artefact is familiar enough—the repetitive nature of production requires only a variation of a common unit; Sturt [17] is an identification of the *craftsman's model*.

The $D1 \rightarrow D3$ shift is also the domain of the *expert*, where one could dispense with the representational stage $D2$. In reality, this is a cerebral faculty, where the craftsman or the expert goes through the known cognitive patterns and only needs to choose a solution that is closest to the requirement, and then extrapolate or adapt from that, keeping the rest of the rules intact. The idea of repetitive use builds up *experience*, which in the long run generates the person's *intuition* which feeds *creativity* [4]. It can be surmised that this model is relevant in all areas of human (and animal) life. The function of intuition is, so to say, much more developed in non-human species. In humans, it manifests itself in the learning processes and is a necessary part of it. It would, in essence, become a part of the *involuntary nervous system*, where the conscious brain has little or does not need total control over it.

6.3.3 Cognitive Models (D*1*)

A major factor that needs to be looked at is the aspect of cognition; cognition is wholly within the realm of ideas, thoughts, concepts and similar; it does not need to be emphasised that even before putting pen to paper creating $D2$, the thought is begun in the head or brain; it can be mentioned that this stage could very well be a *conscious* or an *unconscious* process. Most designers prefer to view it as a conscious process; it is rare that it is not; however, it could be stressed that not enough is known about this area of thinking to say how the whole process happens. Some research has been done to identify some categories of thought and the design process to conclude that it needs much more study. Cognitive models of design are to be reviewed within the framework; the theories of Goel [18], Goldschmidt [19], Tversky [20], et al. are valid for this purpose. Such questions are still being debated at the research level. Pinker [21] questions whether the brain is essentially a *blank slate*; however, current research which studies the brain opens questions that indicates that is it is not so.

6.4 Discussion

Many issues of design lie unresolved, possibly because of its extent. Design lies within a wider field of epistemological studies which encompass aspects from daily use to those with specific requirements; its need varies from medicine to space exploration to art; it is only somewhere in between that the requirements in the stated field of architecture, engineering or design is it is given value.

In the matters mentioned, it could be understood that the importance shifts to secondary factors. It is essential that more discussion is needed on these, and that common aspects are worked out; part of the reason could be that it is closely associated with practice, and not enough attention is given to research. It is time to look at this field as a fuller area of study which encompasses the breadth of application and interest.

Formal models of design started from around the 1950s, when there was interest in systems theory and computational methods of the analysis of operations; time-motion studies began in the early twentieth century, but was restricted within the manufacturing and production environment; essentially this is the $D3$ stage where *efficiency* of construction was looked at, where it is still low. A continuation to this developmental process, interest in *cognitive* work extends to the aspects of the ideation stage ($D1$); the realisation that the $D1$ stage being important has only begun to get its importance. The $D2$ stage actually is where there has been interest for a few centuries, mostly in the arts such as painting and sculpture. Its role in a formal manner is also now of interest. The discussion is incomplete, and there is sufficient scope for study.

6.5 Conclusion

The discussion of the *three-worlds* theory, even though in the epistemological field, should extend to the area of design also; wholesome analysis of the broadest aspects of design beginning with looking at all of existence should become important, especially in today's world when one has to look at its impact on the environment and the future. The process should widen its scope today, with the worldwide concern about the environs, the emphasis on building green, ecological and environmental issues cannot be ignored in design; without doubt the construction and manufacturing industry has had an impact on the current situation. The idea of analysing design from flows of information also should be taken up; designing as information processing could be also be part of future processes. The priority could be to analyse things from the ground up, understanding the long-term impact of processes and materials on the ecology. It could extend down to aspects of daily life, and the life cycle of the configured product.

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Chapter 7
A Concept-Synthesizing Construction Set for Bisociative Thinking

Deny Willy Junaidy, Yukari Nagai, Budi Isdianto and Shintaro Mori

Abstract We designed a puzzle to stimulate bisociative thinking. This puzzle is an educational tool to challenge children's creativity using Koestler's theory of bisociation, which means combining two dissimilar concepts that are not related to produce an unfamiliar and unconventional idea. We explored the possibility of mental imagery formation of a particular creature with physical-ontological puzzle components that rather being ambiguous are in the familiar form of head, body, and support. The absurdity of the puzzle components, e.g. head-body-like components, head-tail-like components, and fin-tail-horn-wing-like components, would reportedly encourage users to generate unexpected imaginary figures that activate imaginative storytelling skills: e.g. 'A finned BIRD crawling in the ocean', 'A winged SNAKE swimming in the sky', and 'A footed FISH flying on land'. The puzzle combinations were observed qualitatively through storytelling (A: Animal; B: Body; C: Capability; D: Domain). The reports show that ambiguous figure combinations have the potential to create rich storytelling.

7.1 Bisociation

Koestler [1] explained the combinatorial nature of creativity, known as bisociation, a collision of two concepts or events that belong to unrelated fields but produce an ambiguous correlation. Bisociation refers to the blending of two incompatible

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concepts which are not normally associated with each other. Cartoon editor Bob Mankoff describes it as ‘a conflict of synergies’. It is a self-amusing event where one seems to be engrossed in the contentment of uncertainty. The courage of being incompatible or uncertain is recognized as a personality trait and idiosyncratic behaviour of notable designers or architects, e.g. Gehry, Hadid, Libeskind, and Mayne [2]. The following are some of their statements that promote the importance of being uncertain and incompatible:

I approach each project with a new insecurity.
I’m not sure where I’m going. If I knew where I was going I wouldn’t do it.
Design manoeuvres gain enough fluidity and freedom to play.
Abstraction opened the possibility of unfettered invention.
I would rather play something completely unheard of, and even with flaws.
If it plays safe, it’s not moving us in the direction that we want to be.
It’s going to begin within a more normative logic, and I’m going to attack it.
The horror is to do something neutral. That’s the failure.

Their statements offer an overview of the importance of maintaining a position in an alienated and uncertain situation which is an essential factor for generating unconventional ideas. In bisociation, a visual pun or paronomasia is a good example of an idiomatic construction of multiple meanings through incompatible wordplay that evokes a humorous effect, for example Richard Whately’s famous wordplay, ‘Why can a man never starve in the Great Desert? Because he can eat the sand which is there’. The vague construction produces incompatible and dissimilar concepts of *Desert-Dessert* and *sandwich-sand which* that create vague definitions within an event that generate awkward realities yet entertain the audience. This awkward yet entertaining event is a favourable ‘ignorance’, known as the pratfall effect described by psychologist Elliot Aronson. It refers to the tendency for an individual’s charm to increase or decrease and make one more humane after the person consciously committing a faux pas or mistake. As in real life, perfection can create a distance, while flaws can turn out to be naturally likable. Conceptual blending in a mental state is a response of genuine unpretentiousness.

7.1.1 From Bisociation to Concept Blending

In further developments in linguistic theory, Fauconnier and Turner [3] introduced the theory of ‘concept blending’ and its formal structure, thus forming the foundations of creative cognition theories and design thinking. Concept blending explains the relationship of the distance between several dissimilar base concepts and the level of abstraction. It explicates the construction of semantic symbols containing elements of analogy, metaphor, idiom, counterfactuals, etc. Conceptual blending is also related to linguistic skills to describe a particular idea differently through mental imagery. Fauconnier and Turner [3] describe a model of creative thinking process through a sailing magazine that reported an event of a sailboat race from San Francisco to Boston. The report creatively combines two distinct boat race events separated by more than one century that took place in the same river: the catamaran boat race in 1993 (real time) combined with the clipper boat race event in 1853. The creativity of the writer in fascinatingly reporting these two different events helped engage the readers in a fantasy. These two input spaces created a blended space. Another example of formal integration is the word ‘boathouse’. Here, ‘boat’ and ‘house’ are not conceptual counterparts, and each has a connection with a different space, land, and water, but in ‘boathouse’, both are conceptual counterparts; thus, ‘boat’ and ‘house’ map onto a single element in the blend [4].

The process of combining two or more concepts is stimulated by intrinsic motivation known as an invisible inner dynamic [5]. This process has been studied, and the concepts have become known as base and target concepts. The invisible inner dynamic measures the distance between base/source concept and the target concept and their relationship with each other. Wisniewski [6] and Nagai et al. [7] conducted in-depth studies of the levels of the concept-synthesizing process that involves typical important concept generation processes: property mapping, concept blending, and concept integrating [6, 7]. They first studied through the concept simulation of two dissimilar base concepts of ‘snow’ and ‘tomato’. The first-order concept generation of snow-tomato indicates a property mapping approach that generates the concept of ‘white-tomato’. A higher-order concept generation of snow-tomato generates the concept of ‘powdered ketchup’ (concept blending). Another higher-order concept generation of snow-tomato generates the concept of a ‘humidifying refrigerator’ (concept integration). The levels are structured as first-order concept generation techniques that explicate the transfer of some features from an existing concept to another concept known as property mapping. Another example of concept generation from two individual concepts of ‘fruit’ and ‘chair’ is as follows:

- *Property Mapping* generates the transfer of features from each concept and yields the concept of ‘banana-chair’.
- *Concept Blending* generates a partial transfer of non-alignable and non-recognizable features from each concept and yields the new concept ‘peeled coating’.
- *Concept Integration* stems from an event in which the concepts of ‘fruit’ and ‘chair’ are interdependent, in-context, and familial, e.g. a chair that is produced similarly to a fruit juice, i.e. picking, washing, peeling, cutting, blending, squeezing, dressing, and infusing. Concept integration plays a considerably important role in the creative design process (see Fig. 7.1).

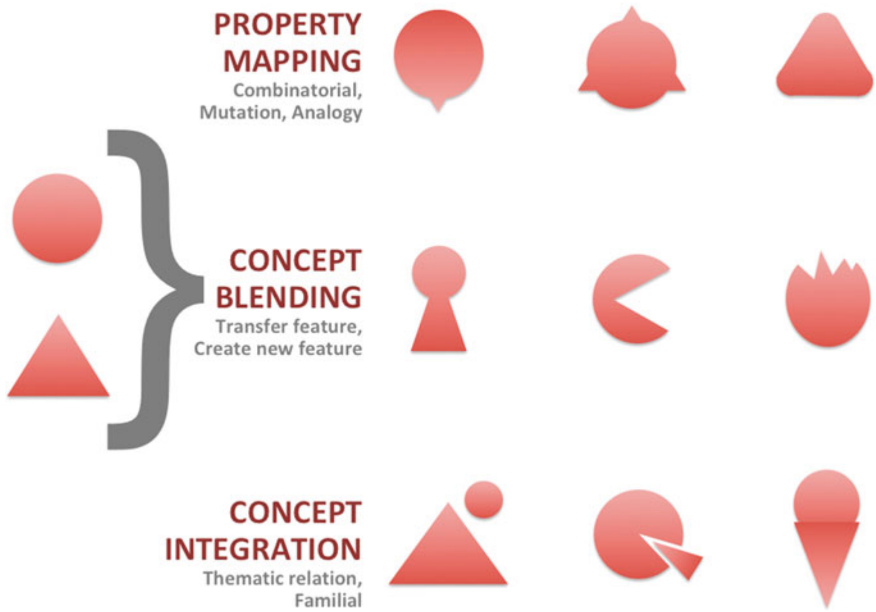

Fig. 7.1 Illustration of a comparison of combinatorial nature of a creativity event. Adapted from Nagai et al. [7]

7.2 A Puzzle to Stimulate Bisociative Thinking

In the mental stage of conceptual blending, ubiquitous everyday language and thought elements from diverse realms are blended in a subconscious process. For creative individuals, experiencing conceptual blending is like enjoying a game, that is being in flow or completely absorbed in the activity. It is a vague emotion, and it no longer matters whether one is at play or work.

Mental representations that are unusual in storytelling appear to be easily stimulated because the conceptual blending seeds merge into the concept and form of this puzzle according to the designers. Borrowing a metaphorical salience theory about matching attribute of the source object and target object, the attribute sets of the target and base concepts of the puzzle design are comprised of dissimilar structures of ontological derivatives, set of head, body, and support, as follows:

- 'Body' is denoted as x with eight modules of fuzzy body-tail-like objects that are likely to evoke their associative characteristic, i.e. feral, tame, innocent, etc.
- 'Head' is denoted as y with eight modules of fuzzy head-body-like objects that are likely to evoke the associative characteristic, i.e. feral, tame, innocent, and/or their associative living domain, i.e. land, sky, ocean, etc.
- 'Support' as z with four modules of fuzzy fin-tail-horn-wing-like objects that are likely to evoke the associative living domain, i.e. land, sky, ocean, etc.

7.2.1 Playing with Bisociative Thinking

Moreover, a successful combinatorial set of *x*, *y*, and *z* is evaluated as a creative concept if it generates unexpected imaginary creatures that uniquely combine some sets of non-alignable or dissimilar features from our common knowledge of understanding of the mental lexicon of semantic memory [8]. As *x* denotes the base concept of body, *y* denotes the base concept of head, and *z* denotes the base concept of support, for the set of *x, y,* and *z* to generate a bisociation, the structure of the ontological derivatives A—Animal, B—Body, C—Capability, and D—Domain should be intermingled, so that they would detach from their familiarity within traditional semantic memory retrieval, e.g.:

- A, B, C, D ⇒ 'A winged BIRD flying in the sky'
- A, B, C, D ⇒ 'A footless SNAKE crawling on land'
- A, B, C, D ⇒ 'A finned FISH swimming in the ocean'

The potential of salience imbalance derived from the construction of ambiguous attributes (non-alignable and non-recognizable) of *x*, *y*, and *z* can be measured by the blending distance of the attributes:

A: Animal; B: Body; C: Capability; D: Domain
[A^1 = BIRD] ⇒ [[B^1 = wing] + [C^1 = fly] + [D^1 = sky]] or
[A^2 = CAT/SNAKE] ⇒ [[B^2 = foot/footless] + [C^2 = walk/crawl] + [D^2 = land]] or
[A^3 = FISH] ⇒ [[B^3 = fin] + [C^3 = swim] + [D^3 = ocean]] into:
A^1, B^3, C^2, D^3 ⇒ 'A finned BIRD crawling in the ocean'
A^2, B^1, C^3, D^1 ⇒ 'A winged SNAKE swimming in the sky'
A^3, B^2, C^1, D^2 ⇒ 'A footed FISH flying on land'
BISOCIATION is a collision of $x, y, z = \{x_{1,..,8}^{\mathrm{A,B,C,D}} \cap y_{1,..,8}^{\mathrm{A,B,C,D}} \cap z_{1,..,4}^{\mathrm{A,B,C,D}}\}$

In a study of creative information exploration, Dubitzky et al. [9] explained that a problem is perceived simultaneously in two frames of reference or matrices of thought [9]. It applies similarly in the event of salience imbalance derived from the ambiguous attributes that create new distance between two orthogonal matrices.

Thus, it could be concluded that the remote distance between the concepts yields unconventional concepts that create distance of semantic ontology in the mental spaces between A—Animal, B—Body, C—Capability, and D—Domain that evoke the surprise of bisociation. Our proposed concept is that players would easily immerse into imaginative storytelling during synthesizing in a fuzzy and vague realm in which they will let go off a priori thoughts and where this construction puzzle could lead to high abstraction in storytelling, implying a creative potential.

7.3 Designing a Fuzzy Puzzle for Bisociative Thinking

This puzzle design utilizes rattan as the main raw material and applies the elastic and flexible characteristics of rattan accordingly. The module is comprised of three rings that represent a set of head, body, and feature in the form of curvy shapes (hereinafter referred to as 'rattanimal', a portmanteau of 'rattan' and 'animal'. In order to stimulate concept blending during future operations of rattanimal, we practiced an abductive way of thinking. Why should a puzzle lead to a closed-ended answer? What if the answer is the puzzle itself? What if one thinks of a puzzling imaginary creature? Thus, an open-ended puzzle allows one to be completely absorbed in redefining and reframing. Initially, we conducted an inventory study of the types of puzzles that are suitable for 9–12-year-old children. At this age, their capability for social conscience and for abstract thought is significantly developed. Next, we narrowed down our idea to a 3D puzzle that is considered to encourage the growth and development of the cognitive aspects of a player by the operation of creative cognition, active fine psychomotor, emotion, and language ability through storytelling. It includes the use of bisociation theory and concept blending, that is combining two dissimilar concepts to produce an unfamiliar concept and potentially be creative [1, 3, 4, 7]. Thus, this 3D puzzle is expected to stimulate a player to be in a fuzzy and vague realm and let go off a priori thoughts. From a vague realm, a player may manipulate the base concept with a rich experience. A composed creature is detached from an existing known reference, for example a bird resembling a fish but that appears to be crawling, or a snake that resembles a buffalo but appears to be flying. This allows a child to manipulate the distance of concept into incredible abstract thinking. This is no longer limited to the first order of concept generation through property mapping, but it facilitates the thinking process to the higher order of concept generation. These three rings offer a noun-noun-noun set to be merged that implicates an increase in abstract thinking. The synthesis of the three noun concepts is capable of generating multiple interpretations. For example, a stem of two nouns, 'fruit-chair', is derived from 'fruit' and 'chair'. The noun 'chair' denotes the following associations: rest, leaning, armrest, backrest, seat, tired, etc. On the other hand, the noun 'fruit' denotes the following associations: freshness, breed, sweet, sour, skin, seed, peel, etc. When the two concepts are combined as a 'fruit-chair', there is a process of selection, adjustment, and a search for annexation/resemblance, resulting in the discovery of unique knowledge. Thus, a fruit-chair in the creative thinking process can generate ideas ranging from property mapping type ideas, i.e. fruitful chair, juicy chair, peeling chair, to concept blending type ideas, i.e. wooden juice, growing screw, peeled coating, etc. Merging two nouns, 'noun-noun', can produce many other concepts. Thus, combining three nouns (noun-noun-noun) is very likely to produce more abstract examples: body(wild, tame)-head(land, sky, ocean)-support(fly, crawl, swim).

7.3.1 Modules of the Puzzle

In this study, to create a salient imbalance of a conceptual puzzle, we proposed an open-ended answer instead. The answer is no longer a completion of the puzzle as it is normally recognized. The open-ended answer of the puzzle contrasts with what is normally practiced when approaching problems of maze. The puzzle does not require a correct or precise answer but an ambiguous or equivocal approach. The puzzle is not intended to be solved and to end at one point, but rather it is an odyssey to decode multiple answers. The more ambiguous the answer, the more curious the result. A tail can be interpreted as a body; thus, a tail can also be interpreted as head, and so on. The distance of dissimilarity in features is a vital factor to determine the blending quality. Through variables A, B, C, and D and variables 1,2,3 … 8 from the source/target *x*, *y*, and *z*, it is possible to access $\{x_{1,..,8}^{A,B,C,D} \cap y_{1,..,8}^{A,B,C,D} \cap z_{1,..,4}^{A,B,C,D}\}$ bisociative way of thinking. Typically, a puzzle is intended to test a person's ingenuity towards certain information. To arrive at a correct solution, one must use logic to look for a recognizable pattern to put the pieces together. The key to successfully resolving the puzzle is identifying a particular kind of order; thus, with inductive reasoning aptitude, a person may be able to solve such puzzles. This puzzle is a set of patterns to be discovered and is a maze that makes it confusing, puzzling, and baffling to successfully achieve a close-ended answer.

Concept blending occurs because of our cognitive ability to connect the dissimilarity between concepts that simultaneously produces a strange feeling and surprise. This distinct bisociative knowledge discovery generates an ambiguous concept such as 'swimming bird' or 'crawling bird'. The concepts of 'swimming bird' and 'crawling bird' stem from the word associations of the puzzle comprised of three modular rings that represent the three available base/source concepts to be blended. The modular set of three rings is comprised of an outer ring, a middle ring, and an inner ring. The outer ring is a set of 'body', comprised of eight modules of fuzzy body-tail-like objects that are likely to evoke their associative characteristic, i.e. feral, tame, innocent, etc. The middle ring is a set of 'head', comprised of eight modules of fuzzy head-body-like objects that are likely to evoke their associative characteristic, i.e. feral, tame, innocent, and/or the associative living domain, i.e. land, sky, ocean, etc. The inner ring is a set of 'support', comprised of four modules of fuzzy fin-tail-horn-wing-like objects that are likely to evoke the associative living domain, i.e. land, sky, ocean, etc. and/or the associative capability, i.e. fly, crawl, swim, etc. (see Figs. 7.2, 7.3, and 7.4). Moreover, this allows one to compose many unexpected imaginary creatures by combining each of the dissimilar structures of ontological derivatives, A—Animal, B—Body, C—Capability, and D—Domain. For example:

[A1 = BIRD] ⇒ [[B3 = fin] + [C2 = crawl] + [D3 = ocean]] or
[A2 = CAT/SNAKE] ⇒ [[B1 = wing] + [C3 = swim] + [D1 = sky]] or
[A3 = FISH] ⇒ [[B2 = foot/footless] + [C1 = fly] + [D2 = land]]

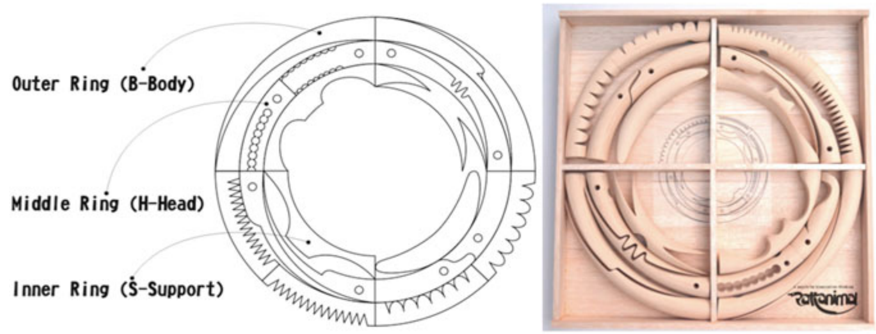

Fig. 7.2 A complete set of a 3D puzzle rattanimal to create imaginary creatures for bisociative thinking

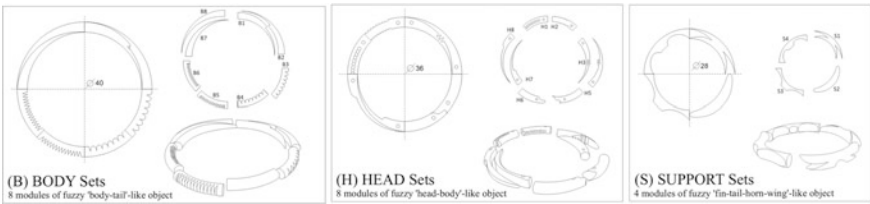

Fig. 7.3 (Left) The outer ring is a set of ‘body’ comprised of eight modules of fuzzy body-tail-like objects that are likely to evoke their associative characteristic, i.e. feral, tame, innocent, etc. (Middle) The middle ring is a set of ‘head’ comprised of eight modules of fuzzy head-body-like objects that are likely to evoke their associative characteristic, i.e. feral, tame, innocent, and/or the associative living domain, i.e. land, sky, ocean, etc. (Right) The inner ring is a set of ‘support’ comprised of four modules of fuzzy fin-tail-horn-wing-like objects that are likely to evoke their associative living domain

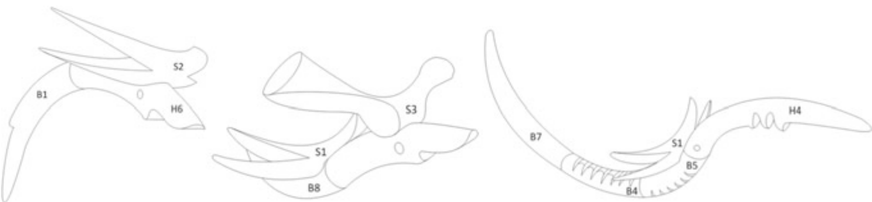

Fig. 7.4 Examples of combinations that produce ambiguous imaginary creatures

7.4 Preliminary Report on the Use of Rattanimal

In the process of developing this product, a team of five independent designers was involved to play this puzzle and qualitatively reported a story about it. However, these designers were not intended as representative target group of the prospective players, namely children.

The following instructions were given:

1. Participants were given one set of rattanimal puzzle.
2. Participants were requested to form two creatures in 15 min from either of the following ideas: a land creature, a sea creature, and a sky creature.
3. Participants were requested to create a story about the two creatures.

Subsequently, each participant narrated his/her story orally. This was recorded in a videotape which was transcribed and coded in the following manner:

A. Common visual abstraction
A: Animal; B: Body; C: Capability; D: Domain
[A1 = BIRD] ⇒ [[B1 = wing] + [C1 = fly] + [D1 = air]] or
[A2 = CAT/SNAKE] ⇒ [[B2 = foot/footless] + [C2 = walk/crawl] + [D2 = land]] or
[A3 = FISH] ⇒ [[B3 = fin] + [C3 = swim] + [D3 = water]]
A normal derivative structure would be as follows:
A^1, B^1, C^1, D^1 ⇒ 'A winged BIRD flying in the air'
A^2, B^2, C^2, D^2 ⇒ 'A footless SNAKE crawling on land'
A^3, B^3, C^3, D^3 ⇒ 'A finned FISH swimming in the water'
Thus, it could be concluded that there is a narrow distance between the mere conventional concepts that evoke no surprise. ***This type of abstraction implies less creative potential***.

B. Distinct visual abstraction
A: Animal; B: Body; C: Capability; D: Domain
[A1 = BIRD] ⇒ [[B3 = fin] + [C2 = crawl] + [D3 = water]] or
[A2 = CAT/SNAKE] ⇒ [[B1 = wing] + [C3 = swim] + [D1 = air]] or
[A3 = FISH] ⇒ [[B2 = foot/footless] + [C1 = fly] + [D2 = land]]
Its derivative structure will be as follows:
A^1, B^3, C^2, D^3 ⇒ 'A finned BIRD crawling in the water'
A^2, B^1, C^3, D^1 ⇒ 'A winged SNAKE swimming in the sky'
A^3, B^2, C^1, D^2 ⇒ 'A footed FISH flying on land'
A remote distance between the concepts potentially produces unconventional concepts that evoke surprise. ***This type of abstraction implies creative potential***.

Reportedly, instead of experiencing ordinary visual thinking of A^1, B^1, C^1, D^1 ⇒ 'A finned BIRD crawling in the ocean', players tend to access multiple possibilities from $A^{1,2,3,4}$, $B^{1,2,3,4}$, $C^{1,2,3,4}$, and $D^{1,2,3,4}$. We think that their high abstract level with a high dissimilarity among those concepts could further lead to another level, e.g. A^1, A^3, C^2, D^3: 'A BIRD-FISH crawling on land'. The time length to exchange, assemble and achieve expected form was quite diverse. Sometimes a decision was taken in less than one minute when players were satisfied with the form. However, there were also players that took up to three minutes to produce an expected form. Quick decisions were possible because players immediately found a unique form, even from a one-time exchange. Slow decisions were made possible because of the players' curiosity over the diversity of exchanging variations up to several times and bring out a possible conflict of synergy (see Fig. 7.4).

7.4.1 Discussion

We analysed the concept generation process by comparing it with the linguistic interpretation process from the viewpoints of thought types and recognition types (commonalities and alignable and non-alignable differences). In evaluating creativity, what goes on inside the head is definitely more essential than mere attention to creative artefacts. Cognitive events in the mind are called 'conceptual space' by researchers of the creative process. Conceptual space is a collection of one or more quality dimensions that are correlated as properties and that co-vary. For example, ripeness and colour dimensions co-vary in the space of fruits [10]. The notion of the category of family resemblance depicts the notion of conceptual distance that is easy to evaluate. Prototype theory suggests that there are differences in the cognitive tendency of individuals to retrieve their knowledge [11, 12]. This particular cognitive tendency is similar in humans who tend to view things from the canonical perspective as looking at objects from high above. Therefore, a selection set of fuzzy stimuli, such as fuzzy head-body-like object and fuzzy body-tail-like object, would distract one's attention from familiar resemblance. [+Wings], [+beak], and [+ability to fly] might stimulate bisociation, e.g. [+Wings], [+horn], and [+ability to swim]. Thus, a conceptual distance is spanned.

Nagai et al. [7] characterize the 'base point' or point-by-point foothold in the flow of the creative thinking process. Just like going to a certain point in a journey, in the journey of the creative process, the end of the journey, which should be clear, is left vague, because the end or target is no longer important in the creative process, but what is important is how to take advantage of the stops on one's way to the end. This is very different from analytical thinking whose orientation is only on arriving at the destination, so that the stops are meaningless. Taura and Nagai [13] explain that the stopping points in a creative process are points of achievement. The point of each accomplishment is a vague idea. The emergence of a vague idea is a sign that someone is at that stop. Often after these vague ideas emerge, when concrete ideas are formed, there is a feeling of dissatisfaction, which leads to a further search for other vague ideas. Thus, vague ideas are the stop points in the 'pathway of the creative process' (see Fig. 7.5) [13].

Fig. 7.5 The rattanimal, a rattan-made puzzle to stimulate bisociative way of thinking. This puzzle allows players to generate creative imagery and improve their creative storytelling skills

7.5 Conclusion

A team of five independent designers involved to play this puzzle and qualitatively reported that it creates a conflict in a player's visual thinking; the attempt to connect dissimilarity between two realms generates a vague concept and estrangement that creates an ambiguous concept like a finned bird crawling in the water. The ability to connect dissimilarity between concepts produces a strange feeling as well as surprise. This distinct bisociative knowledge discovery generates ambiguous concepts, such as 'bird', 'wing', and 'fly' that might not always be imagined as a creature with supporting properties corresponding to air. In the future, the puzzle will be further tested by involving children as representative target group.

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Chapter 8
Fusion of TRIZ and Axiomatic Design Principles: An Investigation in Scalability of System Design Processes to Contemporary Design Frameworks

Himanshu Panday and Bishakh Bhattacharya

Abstract The research paper reflects on advancements in the amalgamation of established methods of TRIZ and axiomatic design techniques in the context of system design. The fusion of problem rendering capabilities of axioms and innovation potential of TRIZ matrix is explored and examined by multiple theoretical standpoints. An analytical conclusion is derived through comparative analysis of contemporary developments in the mixed method technique. Methodological voids in the advancements are also constituted by analogical comparisons in the design cycle. A reference to the human-centered design process is established as a demonstration of scalability of TRIZ–Axiom framework to contemporary multi-dimensional design practices.

8.1 Introduction

Limitless opportunities are being nurtured in the space of multidisciplinary endeavors of systemic innovation. However, the quest for optimal and suitable products is the parameter of competitive advantage in such efforts. Organizations are iterating and redefining their design strategies to maximize consumer satisfaction and organizational growth [1–3]. To foster strategic procedural innovation, companies are deploying numerous methods such as QFD, axiomatic design, TRIZ, TQM, and brainstorming. However, aforementioned tools and techniques have their own comforts and contexts. Merits and shortcomings of these methods have been extensively captured in the literature [4, 5]. To overcome deficiencies, researchers have attempted to amalgamate the design techniques to expand the scope of deployment. As demonstrated by the large number of research endeavors in

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Table 8.1, mixed method approaches utilizing TRIZ and axiomatic design techniques have been the priorities of design researchers due to their competitive advantages over other contemporary techniques [6].

8.1.1 Triz

Designers encounter numerous problem-solving events throughout their design expeditions. Researchers have tried to assist the praxis with tools and guides to aid designer's capabilities in the process. TRIZ (Russian acronym for the theory of inventive problem solving) as an inventive method was pioneered by Genrich Altshuller and his colleagues in 1946 [7]. By studying abstracts of thousands of

Table 8.1 Mixed method endeavors with TRIZ and axiomatic design

Research endeavor	Year
TRIZ applied to axiomatic design and case study: improving tensile strength of polymer insulator [10]	2000
A comparison of TRIZ and axiomatic design [11]	2000
Reviewing TRIZ from the perspective of axiomatic design [12]	2000
Axiomatic design and TRIZ: compatibilities and contradictions [13]	2002
Case study in AD and TRIZ: a paper machine [14]	2004
Conceptual design of a beam splitter for the laser marker using axiomatic design and TRIZ [15]	2004
Improving the acoustics in a historic building using axiomatic design and TRIZ [16]	2005
Conceptual design using axiomatic design in a TRIZ framework [17]	2006
Decoupling process of a coupled design in axiomatic design using TRIZ [18]	2006
TRIZ and axiomatic design: a review of manufacturing case-studies & their compatibility [19]	2006
A conceptual design model using axiomatic design, functional basis and TRIZ [20]	2007
TRIZ and axiomatic design: a review of case-studies and a proposed synergistic use [21]	2008
Enhancing robust design with the aid of TRIZ and axiomatic design [22]	2008
A product design approach by integrating axiomatic design and TRIZ [23]	2011
On the complementarity of TRIZ and axiomatic design: from decoupling objective to contradiction identification [24]	2011
Contributions of TRIZ and axiomatic design to leanness in design: an investigation [25]	2011
Application of axiomatic design, TRIZ, and mixed integer programming to develop innovative designs: a locomotive ballast arrangement case study [26]	2012
Axiomatic design and TRIZ: deficiencies of their integrated use and future opportunities [27]	2015
Applications of TRIZ and axiomatic design: a comparison to deduce best practices in industry [28]	2016

patents, they found similarities in emergence of innovations across the disciplines [8]. Their exploration in the patent literature concluded that technical and physical contradictions were found present in the problem context and an innovation was established when the contradiction was resolved. Altshuller introduced technical and physical contradiction matrix to address the establishments of system void and suggested 40 inventive principles to innovate around the context. TRIZ as a tool allows the design team to recognize and render appropriate unconventional solutions during their design expeditions. Though the method has seen its emergence from mechanical engineering, it has been widely used in various disciplines and contexts [9].

8.1.2 Axiomatic Design

Suh Nam Pyo introduced axiomatic design (AD) as a tool to systemically analyze complex problems and to develop suitable solutions for the requisites [29]. The method is constituted around two axioms—independence and information. Axioms inculcate the universal characteristics of a good design into the product. Independence axiom argues about reduction in correlation between functional requirements and information axiom focuses on reducing complexity in the design solution. Classification of conceptual upbringings is achieved by mapping of design parameters to functional requirements, and nature of design matrix dictates the necessary iterations to attain an optimal solution. AD guides designers to construct a detailed contextual map of the design space and to shape their endeavor around constraints of the design problem. A subjective evaluation can be achieved by reflecting on the consolidation model of creative space and consumer requirements. Axiomatic design methods have been used in various fields such as software design [30], control engineering [31], manufacturing system [32], and product design [33].

8.2 Fusion Frameworks for TRIZ and Axiomatic Design

TRIZ is an effective tool for conceptualizing innovative solutions; however, it lacks a systematic approach to analyze and render design contexts. Although TRIZ proposes a transition of problem definitions into physical and technical contradictions, the approach might not be feasible in complex scenarios. On the contrary, axiomatic design provides a proficient approach to comprehend problem space and to shape the design requirements but suffers from lack of specific techniques for generating ideas. Though AD supports assessment of conceptual upbringings through satisfaction of axioms, TRIZ does not provide a measure to evaluate the outcome of design expedition. Hence, a mixed method approach utilizing TRIZ and AD provides a comprehensive design process benefiting from distinctive features of both the techniques. The complimentary consolidation improves on problem rendering capabilities of axioms and innovation potential of TRIZ matrix. Unification of TRIZ and AD was initiated by associating Su-field modeling of TRIZ and zigzagging of functional requirements (FRs) in AD [34]. Kim and Cochran reviewed TRIZ from the perspective of AD and portrayed synonymies in both the techniques [12]. Major reflections on developments in amalgamation of AD and TRIZ have attempted to analyze possible consolidation parameters for the fusion framework [13, 21, 24]. Multiple researchers have conducted experimental investigations in diverse domains such as product design [14, 15, 35], manufacturing system [10], acoustic engineering [16] to assess the compatibilities of AD and TRIZ. However, the suggested approaches have only been used in iteration of existing mechanisms through inventive means rather than innovating for a major system void.

8.2.1 Methodological Conflicts

Su-field model of TRIZ argues that the existing technical solutions can be modeled using three components—substance (S1), object (S2), and energy (F) [36]. Alternatively, a system shall essentially have three components—a tool (S2) which acts on an article (S1) by the means of energy (F). Substances usually depict technological components of different complexities. Figure 8.1 represents hierarchy in Su-field models of paper feeder component. As demonstrated, the paper feeder acts as a tool when sheets of paper are considered as article. Reduction of the system to next level hierarchy results in replacement of paper feeder as an object by solenoid acting as a tool. Further decomposition can take place through complimentary sensory feedback in the system.

On the contrary, independent axiom of AD restrains satisfaction of individual functional requirements (FRs) by distinct design parameters (DPs). The hierarchy is achieved by zigzagging between functional and physical domains (Fig. 8.2). Probability of attaining an optimal solution depends on definitions of FRs and DPs. In order to affirm axioms, a detailed map of physical variables and functional domain is portrayed through design matrix. A contradiction can be established between three component structure of Su-field model and distinct DP-FR mapping of AD. Triad structure of Su-field model describes physical relationship of its components and their interactions which are hard to portray in case of axiomatic design. However, axiomatic design excels in converting contexts into functional requirements. Su-field analysis may not be fruitful in attempts of converting non-technical scenarios such as enhancing education [33] in triad components.

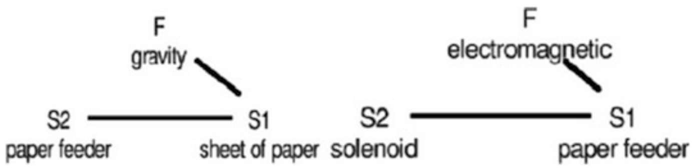

Fig. 8.1 Hierarchal Su-field models of paper feeder component [34]

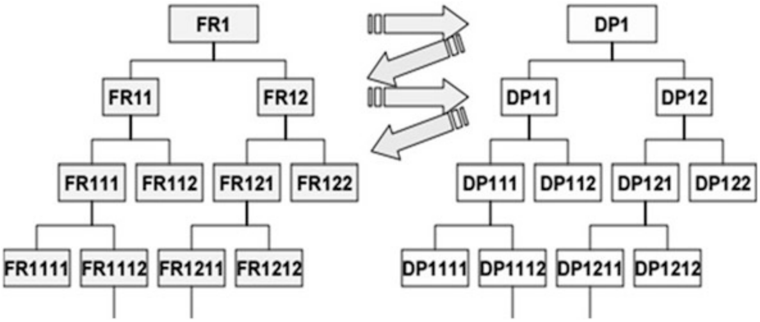

Fig. 8.2 Hierarchal FR-DP structure [33]

Another conflicting standpoint emerges from AD's modeling of information content of system. While axiomatic design expands the independency of required functions, TRIZ possesses methodological restrictions on information content in functional domain. A distinctive portrayal of contextual parameters is needed in order to effectively utilize TRIZ's capabilities. However, unlike TRIZ, AD heavily relies on information modeling in functional domain. The subjective standpoint of AD opposes streamline deployment of FR-DP mapping with a specific TRIZ tool.

8.2.2 Complimentary Standpoints

AD's context rendering capabilities and TRIZ's innovation tools establish value to their fusion deployment in system design practices. TRIZ utilizes technical and physical contradictions to generate innovative solutions. Though AD establishes three types on system conflicts (functional coupling, triangular matrix, and improper DP) [12], it does not provide clear guidelines to invent for the design voids. Kurr proposed inventing through TRIZ in an axiomatic design framework to shape new DPs and to solve functional coupling [34]. When a design parameter fails to satisfy the functional requirement, inventive principles can be used to generate a new set of design parameters to fulfill the FR. A functional coupling can also be resolved employing the TRIZ tools; however, the number of addressable functions will be limited. Kim and Cochran demonstrated the use of physical conflicts of TRIZ in an axiomatic framework to resolve functional coupling [12]. In a decoupled design, arrangement of DPs shapes the design space. A suitable TRIZ technique can be utilized to create a new set of design parameters to satisfy the functional requirements while minimizing their information content. Hence, employing TRIZ in an AD framework enhances the method's concluding product. The approach will be suitable to construct conceptual grounds during abstract phases of design cycle.

8.2.3 Analogous Representations

The ideality principle of TRIZ and design axioms of axiomatic design draws synonymous conclusions of technical evolution. Information axiom states that there should be minimum information in the design parameter of physical domain. The resultants of such constraint will evolve with multidirectional perspective to maintain the suggested edge. Similarly, the ideality concept of TRIZ suggests that the technological systems demonstrate incremental progress in degree of ideality. An ideal system is a metaphysical state which provides interpretations for evolution of contemporary technological systems. Such increments are achieved by increasing the ratio of beneficial functions to undesirable functions in existing system. Terms such as beneficial, harmful, or undesirable represent end user's reflection of product capabilities and hence can be interpreted as qualitative parameters. Though independence axiom and ideality concept appear to emphasize on the same thing, ideality concept's approach is more subjective and accommodative to consider unanticipated parameters for enhancing the product portfolio.

8.2.4 Procedural Voids

8.2.4.1 Inefficient Evaluation Framework

In mixed method approach of AD and TRIZ, evaluation of conceptual upbringings is achieved by analyzing nature of the design matrix. However, the approach is fairly subjective in nature and often fails to summarize the distinctive value of different design parameters to the abstract conceptual phase of design cycle. Though addition of TRIZ tools in AD framework provides coherent guidelines to generate new set of DPs to satisfy the axiom constraints, an objective parametric evaluation is still absent in the approach. Design expeditions often necessitate assessment within conceptual ideas and with contemporary solutions to shape the optimal product. In other words, an objective approach for local and global evaluation in conceptual stage of design cycle is mandatory to establish a satisfactory conclusion in customer domain. However, the existing consolidation model of TRIZ and axiomatic design lacks the ability to effectively assess the derived design solutions and shows an evident need to establish an objective multi-parametric evolutionary framework for local and global assessment during conceptual design phase of design expedition.

8.2.4.2 Limited Contextual Exploration

The applications of TRIZ and AD fusion models have been limited to design and develop solutions related to minor system iterations. Literature provides no evident examples to demonstrate deployment of the mixed method approach to a fairly complex scenario or to invent for a major system void. Lack of database to study the fusion patterns and their conclusions in different domains has resulted into absence of significant insights about effective organization of distinctive capabilities of TRIZ and AD in consolidation. Though new approaches in product design [35] have utilized the mixed method approach within human-centered design cycle, a wider effort is needed to understand and analyze the compatibilities of AD–TRIZ fusion.

8.3 Human-Centered Design and Axiom–TRIZ Fusion

A typical human-centered design cycle includes three phases—discover, ideate, and prototype [37]. Discovery phase of HCD process often deals with articulating the design space and finding related insights to construct upon in ideation phase. Similarly, TRIZ–AD mixed method approach also focuses on effective conversion of customer needs into actionable functional requirements and further on their reflections and interpretations in design parameters. However, the tools in TRIZ–AD methods are more systematic and scalable than subjective approaches of HCD process. In a HCD design cycle, design teams may fall into psychological inertia when developing conceptual ideas for the problem statement. Thus, the resultant product might only be shaped by domain knowledge of team members while a more suitable solution may exist in a parallel knowledge base. However, an effective deployment of TRIZ's physical and technical contradictions to the need statement will support designer to expand their practices for the quest of optimal and suitable products.

HCD process is accommodative to designer's reflection on procedural enhancements and thus, a mixed method tool using TRIZ and AD can be deployed within ideate and create phase of HCD design expedition. The capability of AD's subjective interpretations can be enhanced using two-phase analysis by means of qualitative tools as demonstrated in case studies of product design for the elderly people [35] and health monitoring systems [38]. Further, a FR-DP map can be constructed and TRIZ's contradictions can shape new design parameters. A general evaluation can be achieved by the nature of obtained design matrix. Hence, expanding TRIZ–AD fusion framework with HCD methods will result in a coherent approach to address the concerned design space. However, the elemental meta-physical framework of the design cycle will retain its procedural derivation (Fig. 8.3).

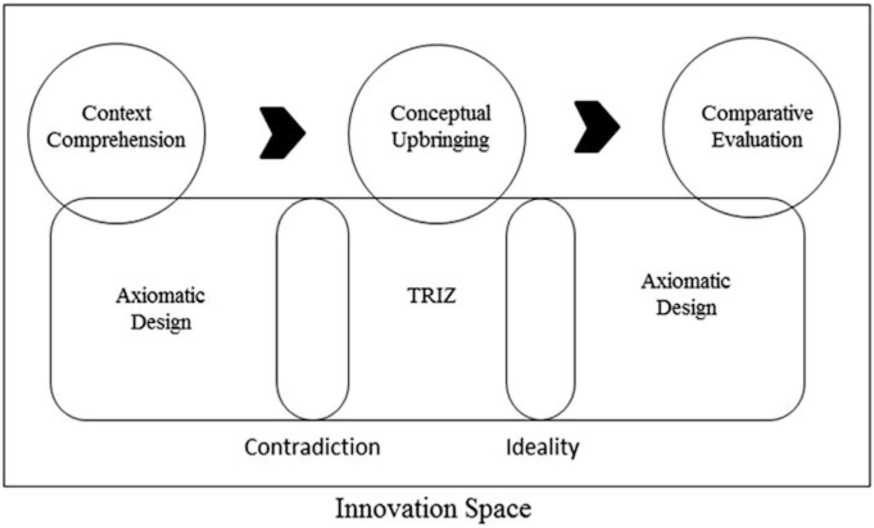

Fig. 8.3 A dominion representation of TRIZ–AD intervention in HCD process

8.4 Discussion

Innovations in system design are fostered by established design techniques to accommodate directives in the process. However, the design approaches have witnessed numerous methodological renovations as a result of rigorous evaluations, constructive criticisms, and pragmatic implementations. These procedural iterations are a result of eminently ingenious nature of design expeditions which compels one to explore and realize multi-dimensional perspective into the product. In the recent years, traditional theories are tweaked for discrete requirements and researchers have attempted to amalgamate conventional establishments of system design.

In this study, a mixed method approach consisting of TRIZ and axiomatic design have been assessed on the basis of compatibilities, contradiction and similarities between employed techniques. Distinctive standpoints have been portrayed to render a comprehensive theoretical conclusion of fusion between TRIZ and AD. Methodological voids of suggested approach have also been constituted to establish scope of further improvements in the research method. Further, employability of amalgamated model to HCD design process in the form of theoretical probes has been suggested to enhance the existing method. In conclusion, it can be established that a mixed method approach of TRIZ and AD does not only overcome their discrete inadequacies but is also scalable to contemporary design framework. In future, introduction of an objective evolutionary approach in the consolidation model will also be researched upon to provide effective assessment of design decisions.

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Chapter 9
Design Templates in Purposeful Games: A Case Study of a Creative Decision-Making Game

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Abstract Designers often work in time-constrained situations during the design process. Among others, one strategy that they use to overcome such difficulty is by using design templates or patterns. A design template is a pre-defined structure of solution, which can be repurposed based on different problem scenarios. The major advantage of using such a template is that the designer does not have to start from scratch, which gives him/her a head start. In this paper, we discuss the use of design templates in game design, which is an under explored area. We also present a case study of how we repurposed the game design template to build a creative decision-making game for novice project managers.

9.1 Introduction

Most artifacts are "designed" to operate in a particular purpose and context. While some contexts pose unique design problems, there are other contexts that have problems common among them. This commonality of problems across contexts gives rise to reusable design solutions or design templates. The use of templates to create designs often gives rise to the debate of compromised creativity. However, use of templates is a trade-off between novelty and time taken especially when designers are faced with non-negotiable deadlines.

The concept of patterns in design was made popular by Christopher Alexander. We quote Alexander: "Each pattern describes a problem which occurs over and

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over again in our environment, and then describes the core of a solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" [1]. While Alexander discusses patterns mainly in the field of architecture, this idea further extends to other creative practices including game design.

Through this paper, we explore the idea of using patterns or templates to design games for training people in decision making. Hence, we look at related work in game design patterns, games, and decision making; we demonstrate how a "scenario-choice" template can be used to build a purposeful game for project managers. Finally, we present a discussion on the implications and possible avenues for future work in game design patterns.

9.2 Related Work

We begin with a review of literature related to patterns in game design. Holopainen and Bjork [2] did pioneering work on use of patterns in game design. They identified pattern by reviewing the literature on existing games, interviewing game designers and analyzing game plays. Some patterns that they identified are last man standing, smooth learning curve, level-based game, time limit, constant activity, etc. Patterns help the game designer in two ways: to deconstruct and understand existing games and to design new games by combining identified patterns in multitude ways. However, in purposeful games (games that are played for a certain purpose in addition to entertainment), the use of patterns for designing is still sparse. The lack of templates for purposeful games is a key motivation for our research.

Within the landscape of purposeful games, we focus on games for learning. Games are an interactive learning medium [3] and offer a more engaging training experience than traditional methods. Learning games also provide other advantages like a risk-free setting, faster feedbacks, scalability, and easier repeat learning. Decision making is a valuable quality at workplace. Some researchers have used games to help people take better decisions in critical situations by reducing their cognitive biases [4]. Scenario-based games are those in which the players are placed in complex problem spaces, which mimic real-world situations. The situations are usually ill-defined problems, often allowing multiple solutions and requiring application of necessary methodologies or tools and collaboration with fellow players or learners [5]. Scenario-based games are found to be effective in training people in decision making. The learning from these games is grounded in situated learning and experiential learning [6, 7]. In the upcoming section, we have demonstrated how a learning game (in a given context) is designed from a template.

9.3 Case Study

9.3.1 Background

The aim is to design a game to train novice project managers in creative decision-making skills. Project management is the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder's needs and expectations from a project. This involves balancing competing demands among—(a) scope, time, cost, and quality and (b) stakeholders with differing needs and expectations (Fig. 9.1).

9.3.2 Creation of a Template

We take inspiration from real life to formulate a template. Every decision-making situation has two elements in common, (a) "scenario" or the situation in which the person is placed (b) "choice" or the options at the person's disposal to overcome the situation. While the situations and choices keep varying, the structure remains. We use these two elements; scenario and choice, from scenario-based games to form the "scenario-choice" template for purposeful games.

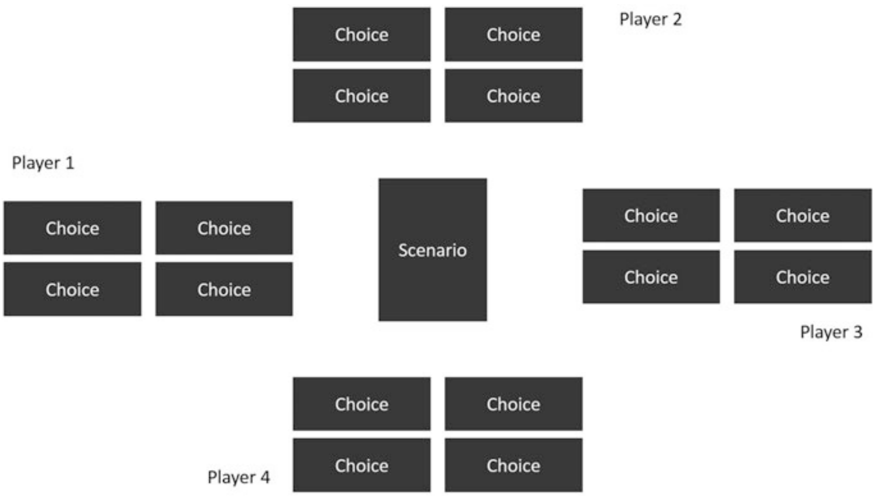

Fig. 9.1 Layout of cards in best choice

9.3.3 From Template to Game

We apply the "scenario-choice" template in the context of software project management to create a card game. We begin with a simple implementation of the template in the card game format. Each scenario (card) would be presented to a player (an independent event, beyond the control of the player) for which he/she would have to respond by playing their choice cards, which will be a limited option. For the content, we compile the list of scenarios and choices in the project management context. Next, we map the scenarios to all the possible choices that can be taken to negotiate it (shown in Fig. 9.2). The arrow in bold refers to the most obvious choice for a given scenario. For, e.g., if the scenario is two main developers in the team want to leave team, then the obvious choice is to approve their departure and hire new developers.

Now we have a list of project management scenarios and their corresponding obvious and non-obvious choices. We remove all the obvious choices from the list of choices (as shown in Fig. 9.3). We use the help of a Subject Matter Expert (SME) to classify options as obvious and non-obvious options. Thus, all the players are left with scenarios and a list of non-obvious solutions to those scenarios. The player who is able to argue and convince the rest of them wins the game.

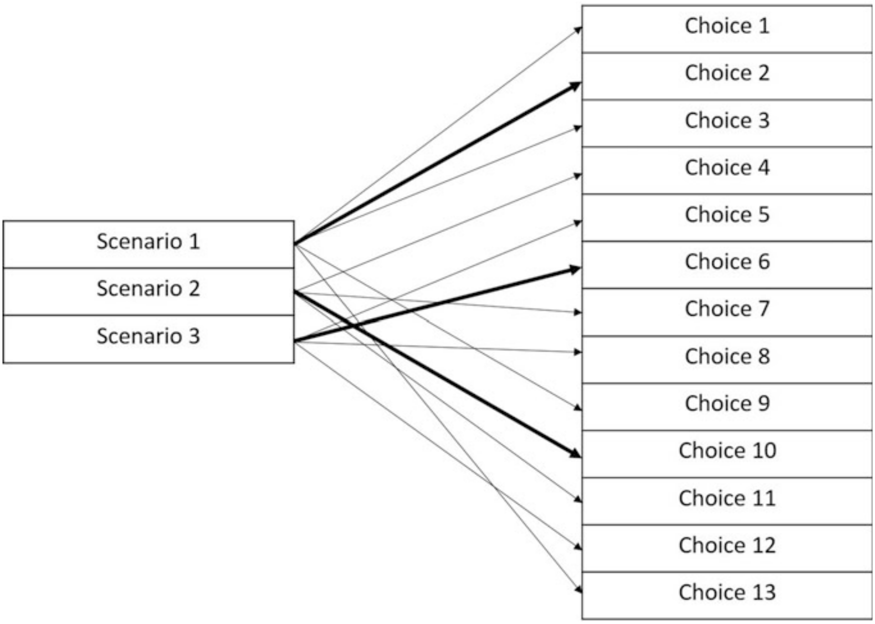

Fig. 9.2 Scenario-choice all mapping

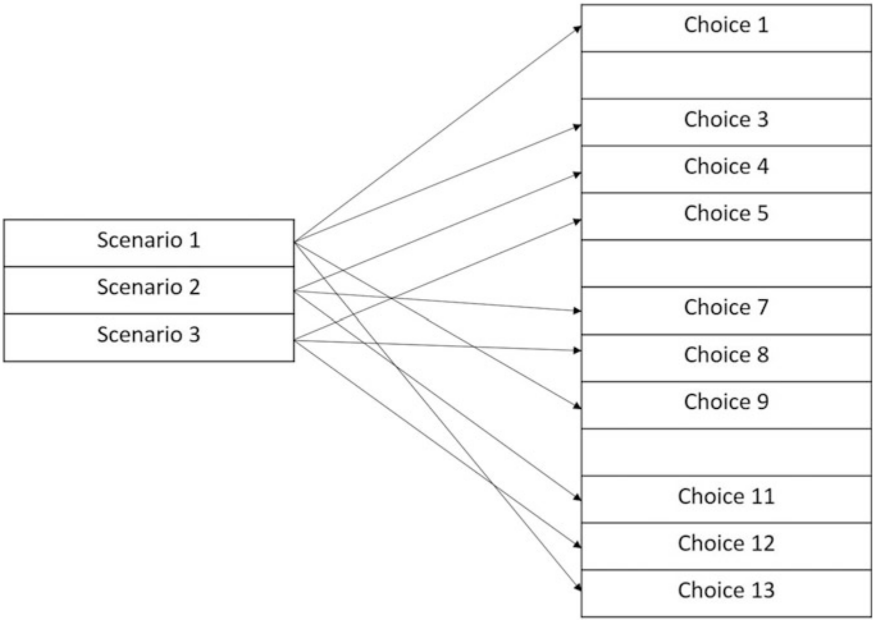

Fig. 9.3 Updated scenario-choice mapping

9.3.4 Brief Description of the Game

The game consists of three main components: the scenario cards, the choice cards, and the tokens. The game is played turn based, when all the players have played it is said to be a round of play. In each round, a scenario card is revealed. The round starts with the scenario cards placed in the middle face down. Each player is handed four choice cards from a deck of choice cards, and the remaining deck is placed faced down next to the scenario cards. At the beginning of each round, a scenario card is revealed from the top of the scenario card deck (see Fig. 9.1). Each scenario card contains a management situation which a manager faces in his everyday work. For, e.g., "Customer suggests drastic change in requirements." The choice cards contains set of actions that project manager can choose from. Some related choice cards to this scenario could be "Convince customer to pay you more," "Negotiate for a deadline extension," or "Give incentives to employees and complete it by current deadline." Each choice in the game has a cost attached to it. The scenarios and the choices are not one-one mapped, i.e., every situation (presented in scenario card) would not have a corresponding "best solution" choice card. This forces the player to solve the problems using choices in hand though non-conventional ways. This step of being unconventional is key to succeeding in the game and is also the purpose of the game. The player then has to convince his/her co-players (peers) that their choice is the best "available" solution. Players then vote for each other's solution to determine the winner of the round. They are not allowed to vote for themselves. The person with the maximum tokens (votes) wins the round.

9.4 Discussion

The Best Choice game demonstrates that the "scenario-choice" template can be used to generate a game in the context of project management. However, we were unable to ascertain the effectiveness of the game from our preliminary assessment. We administered the game to project management graduates and observed the play sessions. We observed that students learnt strategies for dealing with game situations as the game progressed. Their learning was mainly in two ways: one, while observing the consequence of their decisions and second, while observing other players handle similar situations.

The "scenario-choice" template can be repurposed for contexts other than project management. By merely changing only the scenarios and choices to another context, we will be able to generate a new game. For, e.g., we can design a game which trains salesperson in customer negotiation scenarios using the same template. However, this template is not suitable for all learning/training games. For, e.g., if we were to make a game to learn countries and their capitals or currencies then the "scenario-choice" template will be of little use. We find that the "scenario-choice" template to be more suitable for games where there is decision making affecting people. The presence of people in the scenario gives rise to uncertainty in decision making. If scenarios have no ambiguity, then decision making can be reduced to either a puzzle (problem-solving) or an optimization problem.

9.5 Future Work

As the next step, we plan to conduct studies to evaluate the effectiveness of the games designed using the template that we conceptualized. We believe that this evaluation will help us create a mapping between the context and effectiveness of the template. That is to say that some Template A could be suitable for Contexts X, Y, and Z while Template B might be used in Contexts W and Y. The template-driven development of purposeful games is a potentially disruptive approach to game design, as this could help researchers automate the game design process. We intend to, further, build a library of such templates for designing purposeful games. This along with the context-effectiveness mapping would help not only game designers but also non-designers for, e.g., high school teachers, policy-makers, human resource executives, in creating their own games and administering them.

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Part II
Innovation Management and Entrepreneurship

Chapter 10
Integration of Mechatronic Product Development Methods in an Agile Development Area

Kristin Goevert, Maximilian Brombeiss and Udo Lindemann

Abstract Currently, a lot of companies transfer their product development processes from a phase-oriented to an agile process. This paper describes our research on the integration of mechatronic product development methods into the agile development process. The integration of the methods supports agile product development of mechatronic products with the goal to develop better products and increase the success of agile development processes in non-IT areas. For the analysis of product development methods for agile development, a process model with six steps is required. The result is a model, which integrates agile steps with mechatronic tasks and usable product development methods.

10.1 Introduction

Many changes occur in our world and the direction of the development of trends, politics, customer, and project partner is unpredictable. Thus, agility is more important than ever before. To solve the connected challenges in the area of product development, companies try to integrate agile development methods from the software product development to the mechatronic product development [1]. Most of the mechatronic product development processes are structured into different development phases [2, 3]. In contrast to that agile methods help to design a flexible and adaptable product development environment, which supports a shorter reaction time in uncertain situations [4]. Combined to the transfer, a lot of challenges are related to it. One of these challenges is that a lot of agile methods support the project management or are specifically for the software product development and

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not transformable. Scrum is an agile method, which supports project management and is not as much IT specific than other methods. Hence, it is the most transferred agile method [5]. The management methods provide no support on the level of product development. Based on this current situation, our goal was derived to develop an integrated process of agile project elements and mechatronic product development elements. Elements could be methods, principles, roles, processes, and artifacts.

10.2 Research Methodology and Process

The research project follows the Design Research Methodology (DRM) of Blessing and Chakrabarti [6]. The methodology structures the research in four phases [6].

The first phase is the research clarification. A first literature study helps to identify the research gap and goal of the research [6]. This phase represents Sects. 1 and 3.3 in this paper. This phase is followed by the descriptive study 1. This phase conducts a detailed literature study [6]. This research project focuses the analysis on agile and mechatronic processes, principles, and methods. Based on this phase, the prescriptive study is conducted. This phase supports the concretization of requirements, analysis, and solutions [6]. In this phase, the six-step research process shown in Fig. 10.1 was applied. Section 3 shows the steps of this research process in detail.

The last phase of the DRM is called descriptive study 2. This phase evaluates the results of the prescriptive study [6]. The phase evaluates the fulfillment of the defined requirements on the developed model. Therefore, the model is discussed with two experts (Sect. 5).

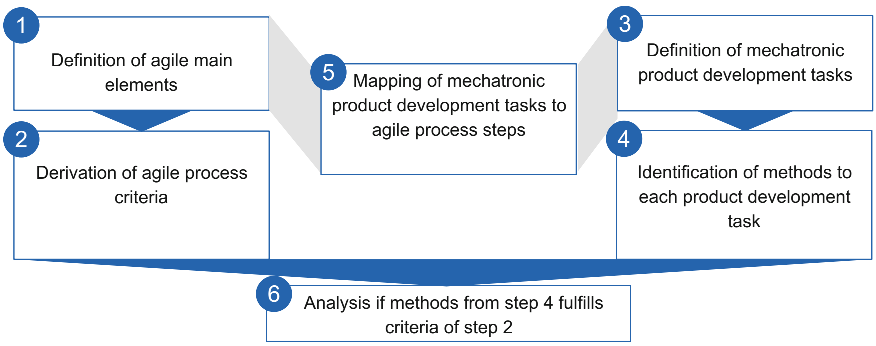

Fig. 10.1 Research process of the prescriptive study

10.3 Literature Background

This section focuses on the literature background of the research: agile processes, mechatronic product development processes, and methods. At the end of the section, the research gap and questions are derived from the results of the literature research and the current situation.

10.3.1 Agile Processes

Agile processes are processes that design a flexible, adaptable product development environment, which supports a shorter reaction time in uncertain situations [4]. The agile manifesto describes twelve agile principles and four agile values [7]. In [3], it is transferred from the software development into the mechatronic product development. The manifesto defines for example that a working product is more important than documentation or that reacting to changes is more important than following a plan [7].

Based on these principles, a lot of methods or processes can be assigned to the agile product development, e.g., Scrum, Extreme Programming, Lean Startup, Design Thinking, and the Agile Hybrid Model [8]. Most of them are iterative processes, which are focusing on continuous improvements and working prototypes [8]. Furthermore, some are some hybrid models already exist. These models like the Agile Hybrid Model are focusing on mechatronic products but only on the project management level.

Hence, it has to be distinguished if these processes/methods support the project management or the product development. Project management defines planning, monitoring, coordinating, and controlling of the project working steps [9]. Product development defines design of subjects, corresponding elaborations, integration of specific design, and the designing of complete solutions [10]. Most of the referred processes and methods are focusing on project management or software specific product development.

10.3.2 Mechatronic Product Development Processes and Methods

Mechatronic product development defines a development of a product, which combines software/information technology, electronic, and mechanical elements [11]. To develop this type of product, different processes exist like the V-model, waterfall model, incremental prototyping, stage gate process, or the spiral model [11–13]. They are different in their sequence but all of them combine similar product development phases like requirements definition, design of the elements, or testing.

Based on the different phases of the mechatronic processes, different method collections for product development exist (e.g., [14–17]). For example, TRIZ focuses on different problem solution and idea generation methods [17]. Other examples are the functional modeling or creative methods like 635-Method [15]. Many further methods exist and are described in the referred method collections.

10.3.3 Research Gap and Questions

On the one hand, the parts of the literature background show the agile point of view and on the other hand, the mechatronic point of view. Existing agile processes and methods are transferred to the mechatronic product development, e.g., Scrum. But all transferred methods are part of the project management. With these agile methods, the developers get only support on the project management level and not on the development level. Based on these findings, the following research question can be derived.

How can the agile mechatronic product development be supported by existing methods of product development without losing agility?

Based on the research gap and questions, the requirements and boundary conditions on the solution approach are defined. The following nine requirements and boundary conditions are derived from literature study, the current situation, and assumptions. They are structured in content (c), modeling (mo), methods (me), realization (r), and assumptions (a):

1. Combination of agile project management and mechatronic development methods (c)
2. No limitations on agility due to the methods (me)
3. General description of the model (c)
4. Relations between the different process modules (mo) [18]
5. Upgradeable model (mo) [18]
6. Applicability in different industries (r)
7. Suitability for Mechatronic product (a)
8. No resource bottlenecks (a)
9. Product increment could be developed from less than nine persons (a).

10.4 Integration of Mechatronic Product Development Methods

This section shows the details of the different steps from the research process (see Sect. 2). At the end, the final model is shown.

10.4.1 Definition of Agile Main Elements

The first step of the research process identifies the agile main elements. The result of this step is shown in Fig. 10.2 and explained below.

Three different types of elements structure the model: principles, roles, and process steps. The agile process is based on four principles and the process is structured in four iterative process steps. It starts with planning of the development sprint followed by the development step. After the development, a workshop to get product or product increment feedback and a workshop to improve the development process and methods are the further steps. The different roles support these agile process steps. One person is responsible for the product, one for the methods and processes, and the other are team members for the development of the product.

The four principles were derived from the twelve principles of the agile manifesto (Sect. 4.1). First, nine different keywords were extracted from the twelve principles and after these keywords were combined and summarized to the main principles. The keywords are: continuous process, self-organized team, customer contact, continuous group work, early delivery, change of requirements, feedback, simplicity, and working product increment. The process steps were derived from the analysis of scrum as the main transferred agile project management method. This process steps are for example also part of the TAFagile framework [19], the Hybrid Agile Model [20], or the Agile Stage Gate Model [12] for example. The process steps are named differently in the different frameworks and are combined in some models. The roles were derived the same way as the main process steps of the agile process.

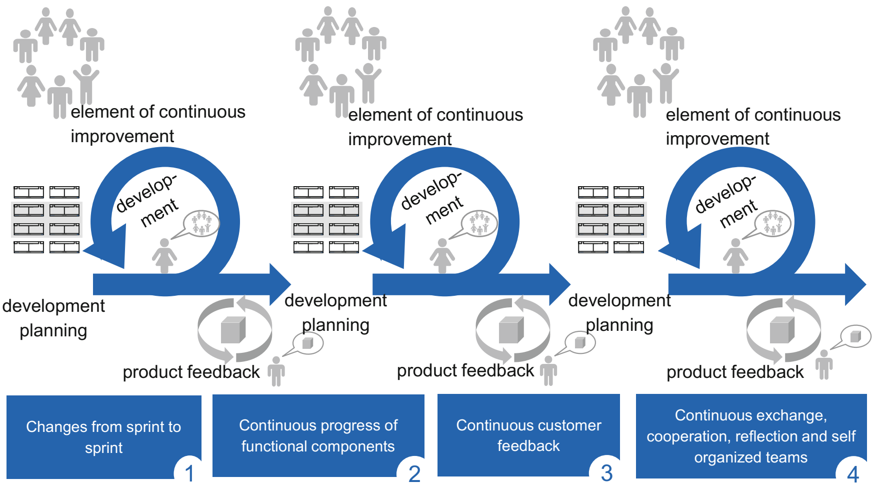

Fig. 10.2 Agile main elements

10.4.2 Derivation of Agile Process Criteria

Based on the identified key elements of agile processes and literature, criteria which describe the key elements were identified (see Table 10.1).

The criteria are clustered into general criteria and criteria for each agile process step. The general criteria were derived from the four main principles (see Sect. 4.1). The criteria for each agile step were derived from the official scrum guide [21].

Table 10.1 Criteria of each agile key element

No.	Criteria	Source
Agile process—general criteria		
1	Change of requirements	Principle 1
2	Focus on working product increment	Principle 2
3	Continuous process	Principle 2
4	Customer feedback	Principle 3
5	Self-organized team	Principle 4
6	Continuous group work	Principle 4
Development planning		
7	Definition of goals	Scrum guide
8	Definition/identification of tasks	Scrum guide
9	Selection of tasks	Scrum guide
Development		
10	Development of products	Scrum guide
11	Focus on development goals	Scrum guide
12	Concretization of the area of consideration	Scrum guide
13	Timeboxing	Scrum guide
Product feedback		
14	Continuous exchange	Principle 4; scrum guide
15	Reflection	Principle 4; scrum guide
16	Result presentation	Scrum guide
17	Feedback on product level	Scrum guide
18	Adaption of tasks	Scrum guide
19	Integration of market impact	Scrum guide
20	Time and budget consideration	Scrum guide
Element of continuous improvement		
21	Continuous exchange	Principle 4; scrum guide
22	Reflection	Principle 4; scrum guide
23	Feedback on process level	Scrum guide
24	Development of process improvements	Scrum guide
25	Planning of improvement implementation	Scrum guide

10.4.3 Definition of Mechatronic Product Development Tasks

The definition of the product development task is based on an analysis of the five different mechatronic product development models (models see Sect. 4.2). Each phase of the models represents one task. The different tasks were compared to each other and summarized in one task-collection. The task-collection includes the following nine elements: system analysis, system design, requirements management, implementation, testing, ideation, integration, risk assessment, and acceptance.

10.4.4 Identification of Methods for Each Product Development Task

After the different mechatronic product development tasks were defined, methods of each task were identified. The identification of the different methods is based on a literature research. 41 methods were identified within the literature research and were mapped to the different mechatronic product development tasks. Table 10.2 represents one example method and how the method collection is structured. For each of the 41 methods, a short description, a mapped task, and a source exist.

10.4.5 Mapping Mechatronic Product Development Tasks to Agile Process Steps

The fifth step is the first step, which combines agile aspects with mechatronic aspects. In this step, the mechatronic tasks are mapped to the agile process elements. The mapping is based on a comparison between the literature definitions of each agile element and the mechatronic tasks. The result of this comparison is shown in Table 10.3.

If the mapping shows an “×,” the task is part of the agile process step. If the mapping shows an “(×),” the task is not directly part of the process step, but the task partially influences the step. The table also shows that no task of the

Table 10.2 Example of a mechatronic product development method

No.	Method name	Short description	Task	Source
1	Functional modeling	Graphic representation of product functions and their relations depending on the point of view (user-oriented, volume-oriented, relation-oriented)	System analysis	Lindemann [15]

Table 10.3 Mapping mechatronic product development tasks to agile process steps

	System analysis	System design	Ideation	Requirements management	Implementation	Risk assessment	Acceptance	Integration	Testing
Development planning				×					
Development	×	×	×		×	×	×	×	×
Product feedback	(×)		(×)	×			×		
Element of continuous improvement									

mechatronic product development is part of the agile element of "continuous improvement." For this process step, existing agile methods should be used or an analysis of further areas has to be conducted.

10.5 Analysis if Methods from Step 4 Fulfill the Criteria of Step 2

This section focuses on the mechatronic product development methods (Sect. 4.4) and their compatibility with agile processes (Sect. 4.2). This analysis is supported by an assessment scheme. The methods were evaluated on their influence on the agile criteria. The methods can influence the criteria in a positive (+), neutral (0), or negative (−) way. The general criteria (see Table 10.1) have to be influenced in a positive or at least neutral way. The methods may not influence the general criteria in a negative way, as this would reduce the agility. Furthermore, the methods were mapped to the tasks and the tasks to an agile process step. Moreover, each agile process step has additional criteria (see Table 10.1). These criteria must be influenced in a positive or neutral way as well, and at least, one of these criteria must be influenced positively. Otherwise, there are no advantages of this method. Table 10.4 represents a detailed view of the analysis. The FMEA, for example, influences two of the general agile criteria in a negative way. Thus, the FMEA is not usable in mechatronic product development process. For example, the requirements list, functional modeling, Method-635, and the Zwicky box influence the general criteria in a neutral or positive way and at least one or more of the specific criteria in a positive way. Hence, these four methods are usable in a mechatronic agile product development.

Based on the analysis and the steps before, an agile model with integrated mechatronic tasks and methods was derived. Figure 10.3 shows one process, the task, and some examples of linked methods. The process can be iterated any number of times. It depends on the development situation and the complexity of the project. Furthermore, the focus on the different tasks depends on the development situation as well and can be redefined in each development planning.

10.5.1 Discussion and Evaluation

This chapter discusses and evaluates the research process and the results. The research process has a strong focus on literature research. Nevertheless, the research process and results were discussed with two experts from the industry. Both work in companies in Scrum teams, which develop different mechatronic products. The feedback from both of them was positive and they said a combination of agile methods and mechatronic product development methods is really useful. Another

Table 10.4 Detailed view of the method—agile criteria analysis

	Agile process—general criteria						Development planning			Development			
	Change of requirements	Focus on working product increment	Continuous process	Customer feedback	Self-organized team	Continuous group work	Definition of goals	Definition/identification of tasks	Selection of tasks	Development of products	Focus on development goals	Concretization of the area of consideration	Timeboxing
ABC analysis	0	0	0	0	0	0							
Requirements list	0	+	0	0	0	0	+	0	0				
FMEA	–	+	–	+	0	0							
Function modeling	0	+	0	0	0	0				+	+	+	0
Method 635	0	0	0	0	0	+				+	0	0	+
Zwicky box	0	0	0	+	0	0				+	0	0	0

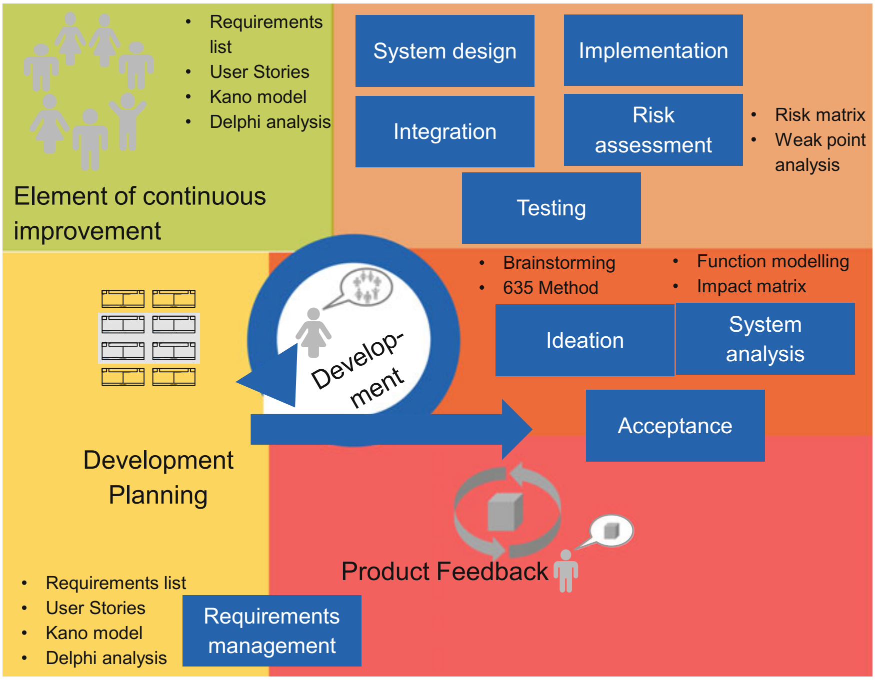

Fig. 10.3 Overview of agile process steps, mapped mechatronic tasks, and example methods

feedback was that the model can be extended to different scenarios. The different scenarios can help to get a better focus in the different sprints to specific task and useful methods. Furthermore, for each method a short description can be integrated with advantages, disadvantages the process, and so on to get a better overview. Nevertheless, the current research is a base, which has to be implemented in an industrial use case as a next step.

In addition to the expert discussion, the requirements from Sect. 4.3 were evaluated (see Table 10.5). The first requirement is fulfilled with the analysis, which mechatronic product development methods links to the agile process steps. The second requirement is mostly fulfilled. The analysis helps to identify that methods which limit the agility and can be excluded from the model. Yet, only an industrial use case can reliability identify agile limitations. Thus, requirement six is only partly fulfilled. The requirements three to five are fulfilled: The model is a general description, is upgradeable, and relations between the different process modules exist.

Table 10.5 Evaluation of the requirements

Requirements	Evaluation
1. Combination agile project management and mechatronic development methods (c)	●
2. No limitations on agility due to the methods (me)	◕
3. General description of the model (c)	●
4. Relations between the different process modules (mo) [18]	●
5. Upgradeable model (mo) [18]	●
6. Applicable in industry (r)	◑

10.6 Conclusion

This paper describes a research process to develop a model, which combines agile process elements with mechatronic product development tasks and methods. With this model agile product development in mechatronic, areas are supported. The research process is a process of six steps. First, agile elements are identified. The elements are four agile principles, three roles, and four agile steps. After that, agile criteria are identified on the level of general principles and for each agile step. At the same time, five different mechatronic development processes are analyzed regarding to the different tasks. For each mechatronic task, methods are identified. In total, 41 methods are identified. After that, the tasks are mapped to the agile process steps and the methods are analyzed with regard to limitations on agility.

This research is a first step and additional research has to conduct. The model will be applied in an industrial use case and new findings have to be integrated. Furthermore, methods for the continuous improvement of methods and processes have to be included as well as different scenarios.

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Chapter 11
Leveraging Design Innovation for Ensuring Creation of Value: An Approach to Identify the Corresponding Design Concerns Towards Enabling the Design Practice

Doji Samson Lokku, Prasad S. Onkar and Deepak John Mathew

Abstract Design Innovation aims at harnessing human creativity for value creation. Towards this aim, Design Innovation attempts to address simultaneously the dimensions of human desirability, technological feasibility, and business viability. The practice of design lends a handle to address each of these intersecting dimensions, whereby it leads to design outcomes, which correspond to respective business elements that are aimed at overall value creation and entrepreneurship. Design combined with Innovation makes the notion of value explicit, as innovation is exclusively about finding new ways of value creation. Accordingly, with respect to the context of Design Innovation, the design practice ought to explicitly address and ensure creation of value. This is where identifying the design concerns, in support of Design Innovation, with its exclusive emphasis on value creation, becomes very important. To this extent, it would require certain study and investigation. This is what has been attempted in the proposed paper.

11.1 Introduction

The context in this paper is Design Innovation, and the focus is on design preparedness to ensure creation of value. In the current state of the art, the notion of value as part of design practice is implicitly present and design preparedness is not explicit about ensuring value creation. To this extent, the scope of this paper is to

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identify and differentiate the design concerns aimed at ensuring value creation. Accordingly, the research question in this paper is how do we identify the design concerns that are aimed at ensuring value creation? What could be the approach for it [34]?

11.2 Linkages Between Creativity, Design, and Innovation

With the underlying basis of creativity, the linkage between design and innovation is established by several research and industry reports. As per Swann and Birke [29, 8], creativity and design are linked to innovation as the first contributes to the expansion of available ideas and the second increases the chances of successfully commercializing these ideas. Accordingly, creativity directly influences design, while design similarly directly influences innovation. Figure 11.1 shows these linkages [13].

11.3 Literature Review on Design Innovation with a Viewpoint on Creation of Value

Several researchers have contributed to the related and associated areas pertaining to Design Innovation, but the criteria for ensuring value creation through design are still elusive. The below content references the work of some of the authors and researchers, who have spoken about and explored in the area of Design Innovation [27].

Heskett [14] is a prominent design historian who has talked about design and creation of value. He refers to design and economics, citing the work on new growth theory and value. Heskett argued that design is needed to establish its own theory of value creation, which would take into consideration both the contribution

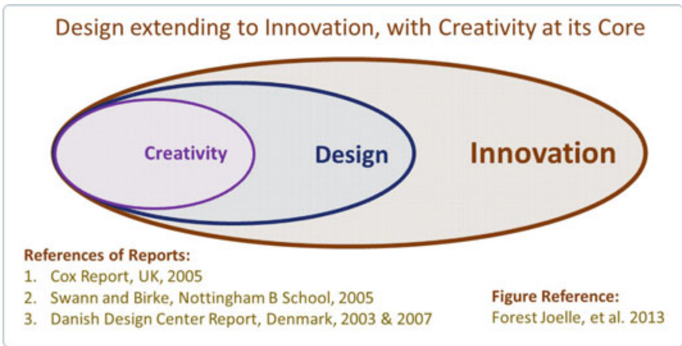

Fig. 11.1 Linkage between design and innovation with common core of creativity

of design to business success and its impact on society and individual lives. Several of his colleagues have continued this research [17].

The publication by Storvang [28] titled 'Innovation through Design', wherein a reference has been made to design practice maturity ladder, clearly positions design as innovation at higher maturity level. Carlos Teixeira [30, 31] has talked about applying Design Knowledge to Create Innovative Business Opportunities. He has published 'The Entrepreneurial Design Curriculum', which advocates for education to impart innovation-related knowledge.

The study by Boztepe [1] has examined the notion of value from sociological, anthropological, and business perspectives, reflecting on what each has to offer to design. Her paper [3] touches upon types of value, design and value, dynamics of value based on the context and time, etc. She calls for further research towards understanding mechanisms of value assignment and creation of value. During DRS Conference [2], she has published about design expanding into strategy wherein she has examined the practices of design firms and their ways of engagement with strategy. As part of this paper, she talks about design's emphasis on user, its emphasis on creativity, and lastly its emphasis on visuals and prototyping. She advocates for more research to uncover design's work at the level of strategy. The report published by Kretzschmar [16] titled 'The Economic Effects of Design' is in support of design aiding innovation and value creation [15].

As per Kumar [18], the perception on innovation has shifted from better efficiency to better fit with the user; thereby, he implies Design Innovation as creating user value. Based on his study of successful innovations, he has identified four principles for practicing Design Innovation. His framework for Design Innovation process consists of seven modes, organized along two dimensions. He has also listed use of several tools for each of the modes, while undertaking 'Design Innovation'. However, the notion of value creation he has not discussed explicitly. Woo [35] has written about 'Holistic Approach to Design Innovation' which describes three stages for Design Innovation, namely research, design, and innovation. This study is aimed at developing a model for holistic design approach, but the notion of value creation is only implicitly present in this approach.

A framework by Mortati [22] describes the linkage between design and innovation that can facilitate discussion about contribution of design to innovation. This paper includes the discussion on value of design as well as its social and economic input to innovation. This framework is put forth by way of open discussion on strategies for change, new firms/entrepreneurs, and designer citizen. However, there is no explicit reference to value creation as such, in this framework description. Another author Chayutsahakij [6, 7] describes a model for 'Human-Centred Design Innovation' with dimensions based on market and technology. This particular study aims to understand the relationship between user research and Design Innovation. Accordingly, the objective was to understand how user research is conducted and applied in a given innovation situation.

The methodology from Candi [5] talks about 'design as an element of innovation' and describes evaluating design emphasis and design focus on innovation. As part of this work, the dimensions of design, namely visceral, behavioural, and reflective, are studied from their respective contribution to innovation. During the DRS 2016 Conference, Braga [4] has published a paper that talks about 'Value of Design'. This author refers to exploring value creation by design as part of future work.

The well-known 'Design-Driven Innovation' by Verganti [33] refers to functionality versus meaning. He has also published 'Meaning-Driven Innovation', wherein it implies defining new meaning while undertaking innovation [24]. With the definition of design 'to make sense of things', as per Verganti, innovation is pushed by the firm's vision about creating new meaning. In the various cases that he has studied, he describes how design has been positioned for innovation. On the other hand, Dorst [9] published a book 'Frame Innovation', which refers to 'framing' as a key concept while attempting to do design and innovation [32].

Most of the authors and researchers who have explored in the area of Design Innovation have worked on either value of design as a practice or the definition of value from design point of view, or they have looked at the connection between design and creation of value, etc [19–21]. As such, these authors and researchers have not explored 'ensuring creation of value' exclusively and how design (as a practice) can enable 'value creation' in an assured manner [23]. John Heskett who has rigorously campaigned for the cause of design to be enabling 'creation of value' is sadly no more.

11.4 Identifying the Concerns Exclusive to Value Creation

The main contribution of this paper consists in these subsections. Since Design Innovation makes the 'value creation' concerns explicit, the following approach is useful to identify those concerns broadly.

11.4.1 Overall Concerns in Design Innovation (DI) Context

Typically, the concerns in design are about conceiving and developing things, which are valuable, whereas the concerns with regard to innovation amount to bridging the gap between a successful design prototype and a committed business venture. Accordingly, this would translate to design preparedness towards entrepreneurship, wherein value creation actually happens, through the execution of corresponding business venture.

Figure 11.2 shows the corresponding depiction wherein the previous Fig. 11.1 as the basis, is further extended to capture the context of entrepreneurship. Entrepreneurship is about wealth creation, and innovation is the tool [10–12]. Accordingly, one can perceive Design Innovation as the preparedness for ensuring creation of value [25].

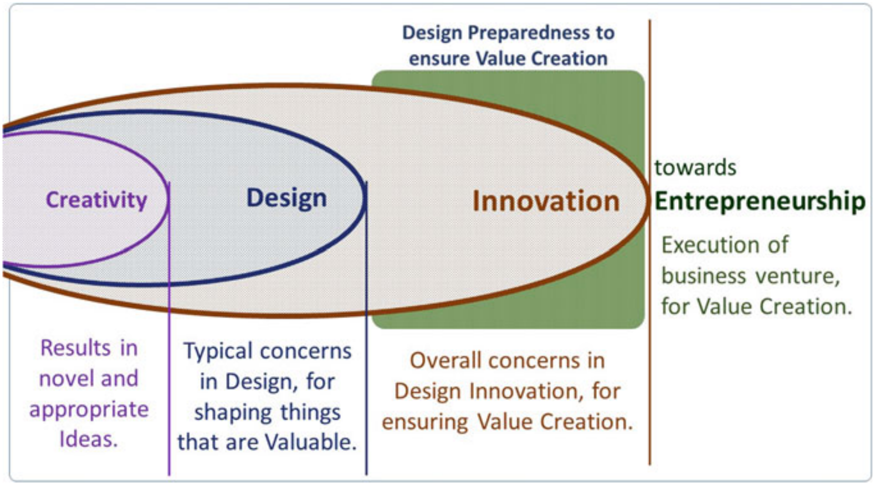

Fig. 11.2 Innovation as design preparedness for ensuring creation of value

11.4.2 Leveraging Business Model Canvas (BMC) Elements

Business models being the rationale behind value creation, they assume significance in this regard. Osterwalder and Pigneur [26] have come up with the popular work aid called business model canvas, wherein nine of its elements are to be detailed out, in order to describe how value creation is undertaken. The reproduced Fig. 11.3 from the related literature refers to four of its elements.

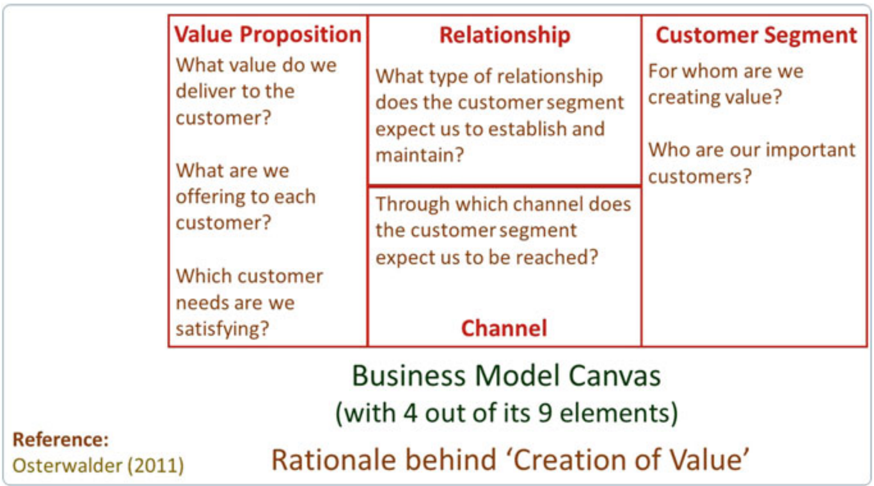

Fig. 11.3 Business model canvas from 'business model generation' by Osterwalder and Pigneur [26]

This canvas consists of elements key partners, activities, resources, and cost structure and revenue stream. However, for the purpose intended in this paper, only the elements value proposition, customer segment, relationship, and channel are made use of. The detailed design can as well benefit from the earlier elements, especially the key activities design.

Typically, any design endeavour would involve design of offerings aimed at a given customer segment. The offerings are supposed to carry potential value for the intended customer segment, whereas the business models are supposed to aid in realizing the potential value. This is where design of business models gains prominence. The above canvas elements lend a handle and guidance with regard to their respective design.

11.4.3 Resulting Approach by Superposing the Previous Two

The approach for identifying the design concerns that exclusively pertain to ensuring value creation can be found by superposing the context of Design Innovation (DI) with business model canvas (BMC) elements as shown in Fig. 11.4. It would result in mapping of the corresponding DI spaces by BMC elements, namely value proposition, customer segment, relationship, and channel. These four elements when superposed on the previous detail of design extending to innovation and entrepreneurship map the corresponding areas and elements and extend the scope of design towards ensuring value creation.

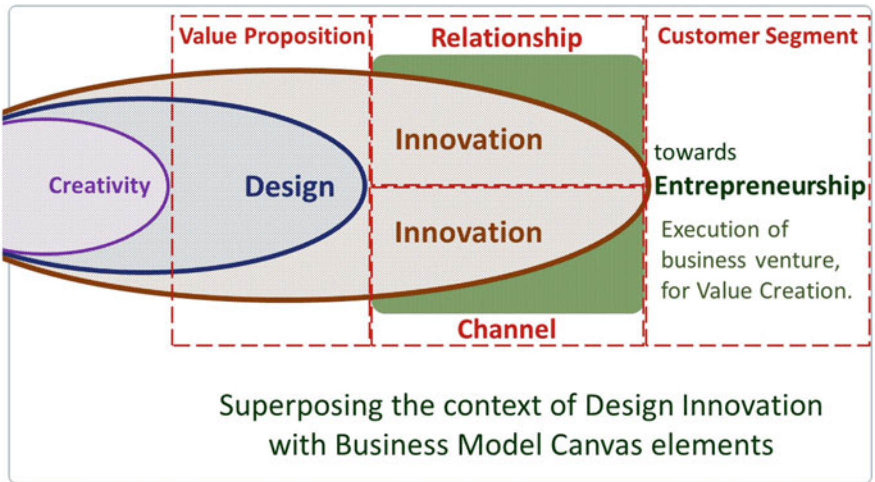

Fig. 11.4 Superposing business model canvas elements to Design Innovation context

Typical design concerns include coming up with a business offering that satisfies a given customer need. Thereby, the business offering will have a certain value proposition aimed at the targeted customer segment. The overall Design Innovation concerns would include taking the value proposition to the customer segment through a channel as well as establishing and maintaining the relationship with the customer. Thereby, it lends a handle to design the whole ecosystem, using which 'creation of value' is possible to ensure. Thus, these two elements, namely relationship and channel, refer to taking the value proposition to the intended customer segment.

Hence, these two elements refer to ensuring value creation and addressing these through design can result in the required preparedness.

11.5 Example Illustration Based on a Hospital Field Study

A field study undertaken at a government hospital in India is illustrated towards describing the overall approach that is put forth in this paper.

11.5.1 Background Context of Example Illustrations

As part of semester project at the institute, field visit to the nearby government hospital was undertaken over duration of 12 weeks, with about a couple of hours of study every week. Despite the conflict with class work at the institute, the study was undertaken during the afternoon period. Since the regular outpatient (OP) consultation closes in the morning at the hospital, the casualty OP (COP) department was chosen for the study. The task was to stay in person in COP for about a couple of hours and observe the proceedings that happen during that period in the department. Being a COP, mainly the accident victims and emergency patients come, often 3–4 victims in about an hour. A large number of people also accompany each of these victims with anxiety, as these are emergency cases. From BMC element point of view, the customer segment is patients and attendants, and value proposition is due medical care administered by the doctor and medical staff.

11.5.2 Example Illustration 1—BMC Element 'Relationship'

The 'Casualty Out-Patient' (COP) Department in a hospital is unique in the sense that patients come here on an emergency due to an accident, or a suicide attempt, or near death illness, and so on. Accordingly, these patients are to be attended immediately as soon as they arrive in the hospital premises. Otherwise, they end up losing time while looking for guidance and direction in which they should go, as they are in a shock and will not be in a position to think nor act.

The study has led to an observation in the form of lack of reception desk for victims who arrive in shock and in emergency. Providing a reception desk at COP would call for the least changes in the current scenario. Accordingly, in the casualty OP, a reception desk is recommended right at the entrance of the building (near to the main door), instead of the currently located nursing station inside the premises. Having a reception desk and someone attending to the victim right away can bring a lot of solace and confidence to the attendant party.

The 'relationship' element is addressed by COP reception desk located right under the portico of the hospital, near its main door. 'COP reception' is manned by a staff member for each casualty case, towards meeting the psychological and medical care needs of the patient victims who arrive in the hospital for emergency medical aid. Since such an intervention amounts to a minor change to the current administrative set-up in terms of posting a hospital staff member and arranging for a desk at the entrance, it is acceptable to implement this recommendation.

11.5.3 Example Illustration 2—BMC Element 'Channel'

Often, the hospital facility is inadequate in terms of availability of stretchers, beds, etc., especially if many victims turn up at the same time or in a lesser time window. It is observed that during usage, the stretchers have blood stains and these are not being cleaned up but used repeatedly by other patients, for lack of time and facility infrastructure. A disposable sanitary bed sheet can make it better if it is available at a nominal price of about 5–10 cents. Providing such facility would require detailed Design Innovation in terms of affordability, availability, and accessibility of sanitary bed sheets.

These bed sheets should be made available right at the entrance/main door of the hospital wherein the victim is brought into the premises. The design should cater to the entire 'channel' ecosystem, keeping in view of the price and access. Accordingly, it exposes the designer to corresponding additional concerns that are to be addressed with regard to the 'channel' element of BMC. In the absence of stretchers, the bed sheet can as well be used to shift the victim onto beds. Affordable sanitary bed sheets, which may be used to shift and handle the victims, could be very useful. If we are able to design disposable bed sheets that can carry the weight of a patient and affordable at nominal price, then it can help these people.

11.6 Summary and Conclusion

An approach by which one can identify and differentiate the design concerns that are exclusively aimed at ensuring value creation has been presented. Having identified the design concerns, the designer can make use of the practice and address these suitably. Such a practice can assure value creation through design. This proposed framework approach would further be developed and strengthened as part of the doctoral studies that are being undertaken currently at the institute.

As part of future research, a few other handles may be developed to identify and differentiate the design concerns that are exclusively aimed at ensuring value creation. The current practice of design also may be re-looked from the point of how similar design concerns have been addressed. Wherever there is apparent deficiency in practice, it may be strengthened further to suit the designer need.

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Chapter 12
Innovative Business Model that Creates Nano-curcumin-Based Enterprise (With Respect to Sustainable Enterprise Management)

Sumit Kumar and Amit Kumar Dwivedi

Abstract In recent years, research on innovation has shown significant potential for start-up ideas with special reference to turmeric. The nano-curcumin has significant properties of nutritional components and thus has the potential for new business development. But at the same time, due to the competitive market and intervention of global players—in regional markets—industries suffer from various obstacles. In such situation, 'business model innovation' works as a core driver to gain competitiveness and superior performance. The paper highlights the Intellectual Property Protection on curcumin-based research and proposes triple helix model that can enable institutions in commercializing IPR that may lead to innovative product development. This study also addresses possible opportunities in nano-curcumin-based product development in the emerging market.

12.1 Introduction

Turmeric (*Curcuma longa* L.) is a perennial herbaceous plant having a short stem with huge extended leaves and ovate, pyriform or cylindrical rhizomes, which are yellow to orange in color and highly branched. In old Hindu medicine (Ayurveda), it is mostly employed for curing sprains and swelling caused by injury [1]. It is the most important spices all over the world especially utilized in Eastern countries [2]. Curcumin is the major bioactive element restrained in *Curcuma Longa*, mostly used in traditional medicine. In recent times, beneficial properties of *Curcuma Longa* were observed helpfully for anticipation and management of several disorders. Today, the nanotechnology plays a significant role in turmeric-based research which helps to increase curcumin's bioavailability and lessen perceived toxicity [3]. Research by Frawley [4] highlights various methods being used for nano-curcumin synthesis, and advanced technology has been patented in the medical field for

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nano-based drug delivery systems. However, limited research works were conducted on the utilization of nano-curcumin in different applications and uses [4].

The aim of the study is to assess India's involvement in order to supply worldwide curcumin demand and business prospects from nano-curcumin-based creations and understanding possibilities of new products. This study also attempts to propose an innovative business model to attract suggestions that can help in formulating new initiatives in the field of production and nanotechnology.

12.2 Literature Review

12.2.1 Use of Turmeric

Turmeric is widely cultivated for its foliage or rhizomes. These rhizomes are preferred as a starch source, flavor enhancer in food and various dishes, colored stains (orange, yellow, citron, amber, blue, greenish-blue, and violet-blue), and basic components in conventional remedies to take care of various disorders including pains, injury, liver disease, and cancers [5, 6]. Turmeric is one of the key crops that are essential for skin care purposes. It is known for use in Indian traditional healing systems, i.e., Ayurveda, Unani, Tibetan, and Siddha, which have included its use in their treatments [2]. It is commonly used in Indian clothing industry as a yellow dye for centuries and also employed as a microbial growth inhibitor in cotton and others textiles production [7]. The *Curcuma longa* plant's extract may help to reduce pest problems in various crop production systems with insect repellent activity against mosquito species [8].

The above-mentioned utilization of turmeric demonstrates the extensive uses of turmeric and the possible scope for entrepreneurial consideration and investigation in the turmeric and its related enterprises.

12.2.2 Trends in Turmeric Industry: National and Global Prospects—A Comparison of Numbers

India ranked first in turmeric production, consumption, and export in the world, and it accounts for 78% of total world production which is followed by Bangladesh, China, Nigeria, and Myanmar [9, 10], and the country contributes almost 60% to world exports. Being the largest producer of turmeric, yet there is a dearth of innovative products, their marketing, and production [10]. A proper research study to understand 'how to create new venture start-ups?' could help to make policies that create entrepreneurs who can utilize the possible resources of turmeric in the country. Only a few studies have been made in order to estimate the use of turmeric in new venture creation.

12.2.3 Research and Development on Turmeric

Indian turmeric is observed as the best in world production due to its high curcumin amount. Curcuminoid, the first major components of turmeric which consists of main curcumin, was isolated in 1815 and chemically configured in 1973 [11]. These studies were successfully performed and tested for development in herbal medicines, pharmaceutical drugs, food processing, food supplement, cosmetics, and natural dyes in textiles industry, insect pest management system, and nanotechnology-based drug delivery system.

Curcumin Resource Database (CRDB) is used to analyze the previous research work and patents published on curcumin since the year 1919 to 2016. The dataset has detailed information about different curcumin varieties, curcumin analogs, molecular targets, research publication, and patents granted worldwide. There are about 176 varieties of turmeric's are grown around the world [12]. According to CRDB, 1186 curcumin analogs with their 196 molecular targets are filled by different researchers. As per this database, one could find out that there about 10,971 research that has been published (Fig. 12.1) and 962 patents have been granted (Fig. 12.2) to different countries on the nature and various utilizations of turmeric. Moreover, nanotechnology-based research also has slight reflections in these patents. The database shows, out of these patents related to turmeric, only limited ($\sim$50) are nanotechnology-based patents in curcumin development. These patents mainly focused on polymer nanoparticles like generic polymers, liposomal, polyethylene glycole (PEG), and micelle nano-drug delivery methods. Pharmaceutical is the only field with the highest research publication and patents for improving medical applications and curcumin bioavailability and efficiency, cancer cure, and drug delivery system.

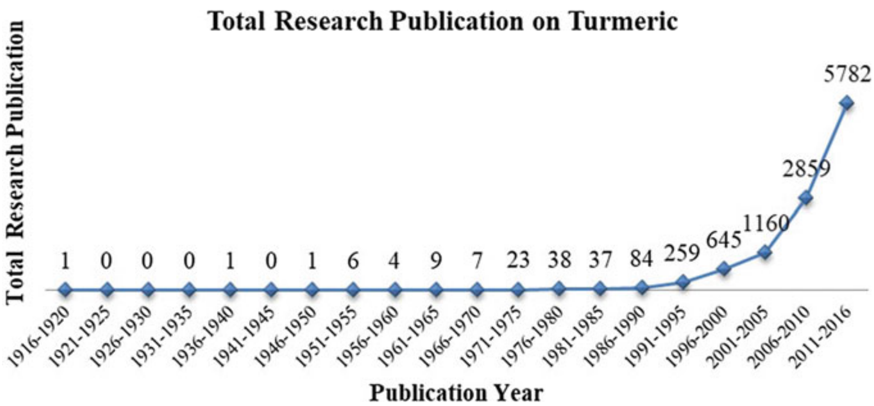

Fig. 12.1 Research published in turmeric (*Curcuma longa*) included nanotechnology. (Kumar [12]; CRDB database.)

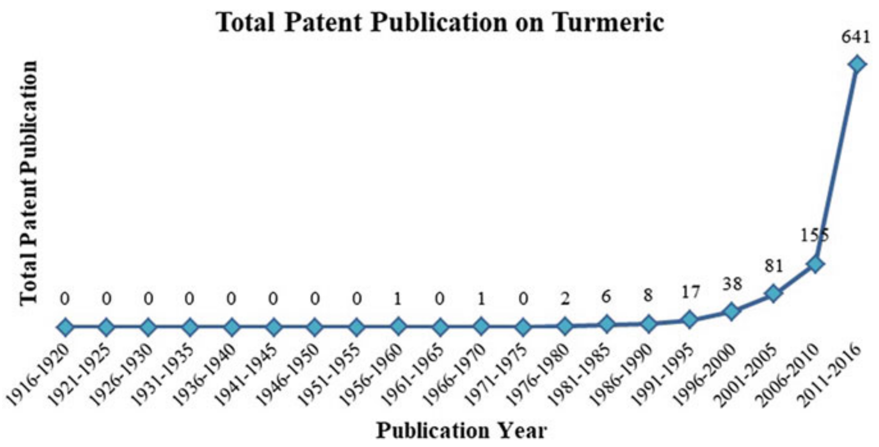

Fig. 12.2 Total patent published in turmeric (*Curcuma longa*) included nanotechnology. (Kumar [12]; CRDB database.)

Only a few researchers have been awarded patents in the food production industry as a food enhancer, additives, colorants, flavoring, and preservative agents [12]. The overall database summary shows the opportunities for the researchers toward commercialization by focusing less explored area.

12.2.4 Challenges and Future Directions for Nano-curcumin-Based Products

Innovations based on advanced technology usually attract attention due to their initiative, but a product must also be useful and compelling to be used in everyday life. Nanotechnology-based industries are facing some common difficulties including time availability, lack of transportation, lack of standards for evaluation, bureaucratic delays, and lack of trained professionals, brand image, and social support [13]. In the different words, there is the absence of industry–academia collaboration for technology transfer, lack of modern infrastructure, the less innovative ecosystem as well as government policies which could help the organization for sustainable growths. In the case of the curcumin-based product, curcumin increased its demand due to possible options in the medical industry. After the nanotechnology intervention in curcumin-based researches, various activities such as bioavailability, antioxidant, antiproliferative, antitumor, antioxidant, antiarthritic, anti-amyloid, anti-ischemic, and anti-inflammatory properties has improved, as providing potential health benefits [3, 14]. Therefore, nano-enabled drug delivery systems have been employed, which show good guarantee in overcoming the difficulty of low bioavailability of curcumin [15, 16]. But due to the various problems faced by nanotechnology-based products, nano-curcumin-based products are also under consideration phase. Companies from the India, Canada, Japan, and USA develop nano-curcumin-based innovative products for the development of medical applications products.

12.3 Business Model Innovation Through Triple Helix Model for Curcumin-Based Products Development

The idea of innovation in business model gain momentum in recent years shows the capacity of a company or firm to create and capture values [17, 18]. Similar research [19–21] indicates that the success of open innovation in a firm is the critical condition of its absorptive capacity. The proper access to skills and external networks seems to be a major indicator of absorptive capacity [21].

Universities now play a dynamic role toward socioeconomic development as well as traditional being hub of human resources and knowledge creation. Moreover, institutions have also brought advancement toward innovations and scientific development. While other existing innovation models emphasize market, state, community-controlled development, triple helix model for innovation distinguishes itself due to its specific characteristics [22].

The triple helix innovation model (Fig. 12.3) based on strategic interactions between universities, government, and industries has played both unifying and overlying roles. It has generated benefits and sustainable economic development in many countries. Researchers claimed that those countries which have used the triple helix model have created innovation driven industries and enhanced their knowledge base. Moreover, universities have been encouraged for technology-based research in these countries [23].

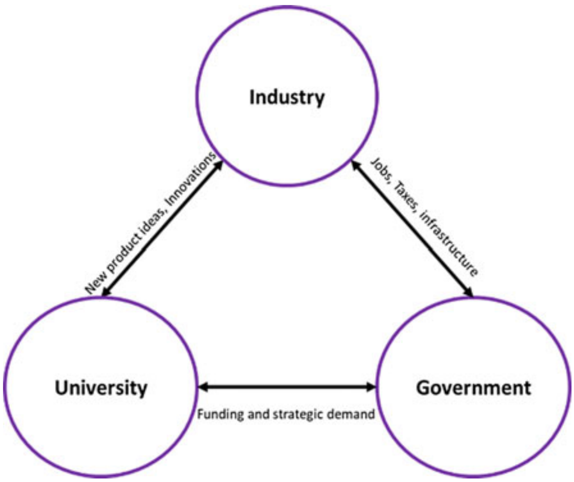

Fig. 12.3 Triple helix model for innovation. (*Source* [24])

The triple helix innovation model would enable institutions to work closely with industry on their specific research assignments. This mechanism would lead to bring innovations from academic campuses which would be industry ready. Also, these kinds of industry–academia collaborations allow students and researchers to work on live projects of industry that apparently yield industry centric innovative products or services.

The triple helix innovation model would enable evolving nano-curcumin-based innovations as:

1. Academic institutions who are working on nano-curcumin would get industry demands for innovative products or services
2. Students who are researching nano-curcumin-based products and businesses would get exposure to from industry experts
3. The industry would get support from academic campuses and research & development laboratories in order to develop products or services
4. The government will be benefitted by innovative businesses where new jobs will be created and the economy will be powered by innovative start-ups
5. Patents and several other right would be attained by academic, R&D, and government institutions which would later on yield significantly to the nation.

The Business Model Canvas can also be used by institutions in order to conceptualize and develop start-ups and new venture ideas [25]. Nine Box Business Model Canvas—which talk about various business plans including value propositions and revenue generation—would be a useful tool for innovators or enterprising students who wish to pursue innovative businesses on nano-curcumin-based products.

In the case of product development using nanotechnology, Hung et al. [26] have found that the commercialization is an important and basic element for emerging technologies, leading to a subsequent technology growth, encouragement of technological innovation actions, and invention of new options or challenges [26–28]. By keeping this in mind, the study reveals various opportunities for entrepreneurs to identify new business and sustainable income through nano-curcumin-based products commercialization process with the help of triple helix model; entrepreneurs may create linkage with research labs for product innovation.

In addition to this point, various sectors such as cosmetics, pharmaceuticals, herbal medicines, natural dyes in textiles, and allopathic medicines need new R&D techniques for innovative product development. Entrepreneurs can discover various opportunity for new product design in food processing industries involving nano-curcumin in various food flavoring, food preservatives,food packaging and another purpose [27, 29]. For proper commercialization of nano-curcumin-based products, entrepreneurial marketing is also needed. It is also observed that there is a lack of awareness among consumers about nanotechnology-based products resulting in low presence and utilization of nano-curcumin-derived products in the market. With the help of a triple helix model, government agencies could help the organizations by creating the awareness of the products. Moreover by Proper channeling for nano-curcumin derived products could create various opportunities for B2B, B2C businesses. Companies can also commercialize nano-curcumin based products in the market with fruitful margin.

12.4 Conclusion

Recent research studies have shown that involvement of nanotechnology turmeric-based production illustrates a high application in pharmaceutical-based industry broadly. A diverse array of nano-curcumin is derived from enhancement of natural dyes for textiles, various flavors, and preservatives in food processing in order to improve the usability of herbal medicines and nano-pigment in cosmetics, etc.

Nanotechnology is a multidisciplinary field that can be used for a variety of innovations and development of curcumin-based products for efficient applications. To conduct innovative research in this field, the triple helix model could help linking between R&D institutions and companies that enable technology transfer. This process would ignite new venture ideas that can create first-generation entrepreneurs. Also, the Indian research authorities require upgraded infrastructure, innovative ecosystem, and favorable government policies to create more innovative and cost-effective products for our industries.

Limitations of the Study: The current research work is based on the secondary data available in this field; therefore, a comprehensive account of field level difficulties and possibilities in nano-curcumin-based products could not be monitored.

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Chapter 13
Transformation Is a Game We Can't Play Alone: Diversity and Co-creation as Key to Thriving Innovation Ecosystems

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Abstract Innovation ecosystems and their prosperity have drawn increasing interest in research and practice. Through a literature review, diversity in terms of the types of collaborators and the nature of interactions are identified as key ingredients for innovation ecosystems to thrive. Co-creation practices and culture help coping with inherent, added complexities in the collaboration among actors and create more sustainable, mutually beneficial value for all stakeholders in the ecosystems.

13.1 Introduction

Innovation ecosystems, often being region specific, have increasingly gained ground in the literature on innovation, strategy and university–industry collaboration. They have drawn interest specifically due to the opportunity to gain competitive advantage on a firm level but also to drive sustainable growth on a regional and even national level. Scholars have developed a number of definitions and labels such as open innovation [1], innovation clusters [2–6], innovation networks [7], innovation ecosystems [8–10] and triple or even quadruple helix models [11, 12].

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Generally, innovation ecosystems consist of a number of symbiotic economic and sociological interactions between actors or entities [2, 8]. A well-established combination of these entities involves private sector, academia, including universities and research organisations, as well as public sector (like governmental bodies) and citizens living in interdependent relationships and creating mutually beneficial value to the society [2]. Furthermore, innovation is said to lie in the intersection of different bodies of knowledge and diversity has a tendency to increase the likelihood of innovations to emerge [13]. Despite the extensive literature to date, research calls for a further understanding of the successful implementation of innovation ecosystems specifically through a people-centric lens [14]. Moving beyond transactional collaboration and with the thought of mutual value creation and interdependent relationships among a diverse group of actors, a more holistic perspective on ecosystems [15, 16] and opportunities to draw inspiration from co-creation needs to be taken [17].

Hence, this paper sets out to deepen our knowledge on how diversity can be embodied in ecosystem context and what are possible co-creation processes enhancing innovation ecosystem success. We approach this topic through a systematic review of extant literature from innovation, engineering and design, but also organisational management, cognition, and adjacent fields. We specifically focus on eliciting how to enhance diversity of ecosystems on multiple levels—and across these—as well as to provide practical implications on how to effectively achieve it. Continuous cross-pollination of ideas, knowledge and technology between actors is fundamental to introducing innovation and a more divergent combination of these elements increases the chance for innovation to emerge. In this paper, we will first explore how diversity can be introduced on three levels (macro, meso and micro) among the collaborators. This is followed by examining the diverse nature of interactions and its impacts, and finally, we will explore how transition towards co-creation practices and mindset/culture can facilitate coping with the inherent complexities of collaboration in diverse settings.

13.2 Diversity in an Ecosystem and Its Link to Successful Innovation

The benefit of diversity for innovation processes and knowledge creation has been highlighted by numerous scholars [1, 18–21]. Based on the literature review in the fields of innovation ecosystems and diversity, a framework was formed as a result categorising different types of diversity among collaborators and/or entities. The framework differentiates three different levels: sector (macro), organisational (meso), and individual (micro). Named as multi-level diversity framework (Table 13.1), it illustrates how diversity can be impact innovation ecosystems on multiple levels. The central literature underpinning the framework is explored in more detail in the following subsections.

Table 13.1 Multi-level diversity framework

Collaborator level	Dimension	Impact on ecosystems
Sector (macro)	Types of sectors	Management of risk Spark new insights and novel solution combinations/ideas
Organisational (meso)	Vertical–horizontal partnerships Types of organisations Sizes	Advanced capacity and resources additional paths to market Incentive for competition and differentiation Security to use new technologies Distribution of risk in R&D Spark new insights and ideas Creation of new/unique knowledge
Individual (micro)	Qualifications Knowledge/expertise Culture or nationalities Novelty in an industry sector Diversity (inherent or acquired) Established vs new relationship	Spark new insights and ideas Cross-pollination/-fertilisation of knowledge Deeper understanding of new opportunities, users and market needs

13.2.1 Diversity on Macro-level

Diversity at sector level can impact on ecosystems essentially in two ways. Finding the right balance between specialisation and diversification is key to robustness in economic and societal changes [22]. The dot-com boom in early 2000s (and subsequent collapse) had a major negative impact globally on the information technology sector including the one in Silicon Valley illustrating the vulnerability to market turmoil if an ecosystem is highly dominated by a single industry sector, expertise and focus on a small market section. What sped up the recovery process was the strong presence of other sectors ranging from biotechnology, medical devices, aeronautics and medical devices [23, 24]. In addition to managing risks for long-term sustainability through staying insight of alternative markets, a more diverse mix of sectors in an innovation ecosystem can significantly raise the likelihood of novel solutions to form as unconnected ideas, methods and technology can merge into innovative breakthroughs [13, 18].

13.2.2 Diversity on Meso-level

Diversity at an organisational level (meso) can create multiple benefits and specifically from an organisation's perspective collaborating beyond organisational boundaries has been identified as highly beneficial. The number and diversity of direct connections a company has can boost its innovation capacity, when well set-up and managed [25]. Similarly as to the sector level diversity, risk reduction in research & development can be achieved by having a number of collaborators as activities can be distributed among them. In addition, it may give a confidence boost to the rising uncertainty of the development and application of new technologies. They also reduce associated ambiguity of innovation and facilitate information streams to accelerate [26].

Diversity can be identified and introduced in vertical (such as suppliers in the supply chain) and horizontal (e.g. direct peers within and between industries including education and R&D companies) partners of the organisations [5, 27, 28]. The benefit of horizontal and vertical partners is demonstrated in two different ways. Collaborating, horizontal partners will end up racing against and pushing one other, and as a result create an important incentive for innovation and differentiation, especially in the context of early stage cluster formation [2]. On the other hand, vertical links such as customers and suppliers incentivise market and production demand and therefore promote growth [29]. In addition, these relationships provide a unique type of knowledge that is solely accessible to the partners within the ecosystem and thus can lead to competitive advantage. The literature suggests that complementary investments aimed at acquiring a deeper understanding of the market, e.g. from competitors or customers, can increase the organisational performance significantly [30]. To avoid the risk dependencies and to hold ownership in decision-making, an organisation should liaise with a number of partners. These collaborative settings should ideally represent public and private sectors as well as research organisations to maximise innovative outcomes [31].

Finally, a factor mitigating the economic volatility is the vast number of organisations of varying sizes [32]. An appropriate example may be found in Finland where Nokia's decline in the mobile phone market boosted the Finnish start-up ecosystem. Former Nokia employees transitioned to founders of new ventures and start-up support organisations contributing to the blooming yet previously almost non-existent entrepreneurial tech sector [33]. Before, the national economy was too reliant on a small number of traditional, established and large-scale companies. Despite the national crisis the Nokia crash caused, the local economy was able to create a more balanced mix of corporations, including a significantly higher number of diverse organisations: from small- and medium-sized companies and start-ups to large corporations [34].

13.2.3 Diversity on Micro-level

Within both sector and meso-level, collaboration mainly occurs among individuals (often called micro-foundations/micro-levels of innovation) and there is a variety of ways to include diversity in such collaborative situations within and across stakeholders. As discussed previously, innovation occurs at the intersection of different bodies of knowledge with the greater potential for innovation the more diverse the inputs. Research has shown that an organisation with diverse staff tends to clearly outperform those where employees have more homogenous backgrounds [35]. Heterogeneity can come from through inherent (traits people are born with) or acquired diversity (traits gained from experience). As such, team compositions should include collaborators with different qualifications and expertise [36]. Also, inherent diversity, e.g. age or gender, more accurately manifests the construct of the society or the marketplace and, therefore, the organisation is able to discover unmet needs or untapped market segments. User needs are better understood by a team, in which at least one team member has mutual traits with the end-user [37]. Furthermore, diversity as per cultural background and nationality puts a team in a better position to question assumptions and societal norms. A high percentage of people from different national and cultural backgrounds has been one of the enablers for the mentioned ecosystem success in Silicon Valley [24]. Finally, it is beneficial to combine both inherent and acquired diversity traits in an organisation or a collaborative setting to achieve innovative outcomes as it creates an environment where unexpected ideas are heard. Acquired diversity specifically plays a major role in allowing employees to express their ideas and to feel they are being valued [37, 38].

13.3 Collaboration Ties and Relationships

Apart from the diversity of the actual stakeholders involved in a network, the way collaboration ties are formed between them is equally important for the success of an innovation ecosystem [39]. Collaboration ties refer to the nature of interactions between stakeholders and what is effective in a particular context. Whilst diversity of participants can be instrumental for an ecosystem to prosper, collaboration ties between actors determine if the collaboration will be successful, or not. Different types of collaboration ties and their impact on the successfulness of a collaboration are explored systematically in the following, based on the extant literature and are summarised in Table 13.2.

The first dimension we will look into is the *formality* of a collaboration tie. Specifically, we discern between formal and informal ties, which may occur in corporate alliances, project work or, at a higher level, through participation in industry-specific associations. A formal type of collaboration is suggested to facilitate reciprocal transfer of explicit knowledge between organisations or individuals, which can facilitate the execution of set tasks in a project. In innovation, novel thought, however, often emerges in a rather unpredictable manner, for which informal communication, sharing tacit knowledge and engagement in joint practices are essential. As such, open forums that foster more informal types of communication are often key in making sure an innovation network functions well [39]. In fact, beyond fostering informal exchange, it seems it is indeed the *absence* of formal structures, providing a relaxed and mutually trusted environment that intrinsically motivates individuals to collaborate and work towards a common objective, much

Table 13.2 Variety of collaboration ties and their impact on development activities

Type of relationship	Impact
Formality of ties	Informal ties: effective in task exploration and sharing tacit knowledge (mutual trust required between stakeholder) Formal ties: effective for executing set tasks, mainly relying on explicit reciprocal knowledge sharing
Strength of ties	Strong: mitigates barriers for open transfer of knowledge Weak: connect otherwise separated social groups
Number of collaborators	Lower: balanced value creation, reduced negotiation competitions Higher: increasing efforts to manage network and negotiate goals
Maturity of a relationship	Old: diversity and novelty of ideas New: diversity, novelty and uniqueness of ideas

more effectively and in a self-directed manner. This motivation—and its reliance on mutual trust—is typically directly linked to the network's overall purpose. If the network has mainly *perform*ative objectives (i.e. reach a specific outcome), for instance, sufficient trust can be ensured through relevant contract agreements. For *transform*ative goals (i.e. exploration of opportunities), which is much more uncertain, trust in the partners' native abilities to work jointly and communicate openly is essential [40]. By and large, informal collaboration ties facilitate joint exploration and reinterpretation of knowledge and ideas and trigger tacit (potentially unrelated) knowledge to be shared ad hoc, which likely leads to new discovery. Formal structures, in turn, are vital when it comes to implementing solutions and/or executing clearly defined tasks along the innovation process. Innovation ecosystems require both types of relationships.

Relationship types can also be described as per their particular *strength*, which reflects the time and effort invested in building the relationship, and also is a measure for the resulting emotional link between partners. Both strong and weak ties are equally important, each for a different purpose. Similar to the formality of a collaboration discussed prior, stronger relationship ties foster ad hoc transfer of (tacit) knowledge, but might get in the way of search and exploration activities (as information shared is more likely to be already known by both partners). Weaker ties, in turn, help in the earlier, exploration phases of a project, though individual activities might have to be managed more closely [39]. Weaker ties contribute to innovation as they tend to connect otherwise disconnected social groups. As such, fewer social conformities apply, hence allowing more flexibility for experimentation and diverse knowledge to be combined and spawn new ideas [38].

The literature suggests another important factor, which pertains to the *number of collaborators* in a network [41]. Particularly, connections across organisational boundaries, potentially also involving (local) communities, are suggested to have a clearly positive impact on innovation. The reasons for this are rooted in the dynamics of collaboration between two as compared to more parties. The more parties there are the less likely are self-interests of an individual entity to prevail, due to a reduced bargaining power against other participants, also facilitating fast conflict resolution [41].

A final issue worth mentioning here is the *level of maturity* of a relationship (established versus more recent), when it comes to novel ideas being created in an innovation ecosystem. The literature suggests that creative thought is enhanced, at individual and group levels, when more time is invested in exchange with a more diverse group of people, i.e. acquaintances or even strangers, as compared to only be sticking to colleagues or long-time partners [38]. Therein, it is important to keep connecting to new people regularly, as, naturally, the innovation stimulation effect wears off as more time is spent with others. This is simply because it leads to a decrease in the amount of non-redundant information that is/can be shared between participants.

13.4 Shift to Co-creation Practices and Collaborative Culture

Building on the discussed insights, it is apparent that increased diversity in the collaborators involved and of the relationships they have can add substantial value to an innovation ecosystem. Yet, it stands to reason that adding diversity to an ecosystem and introducing novel actors/stakeholders brings about significant challenges in terms of collaborating seamlessly. It can reinforce the tension between required dynamics (to foster novel thought) and desirable stability (to produce outcomes reliably). Missing trust in novel entrants to a network can hinder transfer of knowledge and thus inhibit open collaboration [42]. The multi-layered character of an innovation ecosystem, diversity of involved actors and increasing demands of co-creation activities make it difficult to manage collaborations effectively and, therefore, exacerbate the challenges in knowledge exchange. An early and/or particularly novel/surprising discovery and the successful exploitation of the resulting opportunity can help the network to grow strong right at the start. Though, the effect can also be negative, depending on the trust and openness in the network, for instance, when individual stakeholders want to take ownership of a new idea [40]. This risk can be effectively mitigated explicitly emphasising the concept *co*-creation and of a collaborative culture, rather than allowing silos to form. There is, however, no magic formula or clear-cut recipe as per how a successful innovation ecosystem can be created and maintained [30, 42]. Each ecosystem and stakeholder network is different and needs special attention. It is imperative to truly understand the needs and goals of all actors, their context and culture, in order to select appropriate mechanisms that facilitate the building process of ecosystems along the way.

Co-creation is defined as collaborative, joint acts of creativity, i.e. creative problem exploration and solution finding carried out by two or more people [43]. In other words, it is a collaborative effort of multiple stakeholders with the intent of working towards a common, (novel) goal [44]. In trying to implement co-creation in industrial practice, it is vital to consider a multitude of principles to achieve the desired outcome. It does not happen by itself, but demands concerted planning and true integration into the activities of the innovation ecosystem. Probably the most important part is suitable time management. This is due to a more complex project set-up, involving multiple actors, to equally create more complex barriers for collaboration, which have to be addressed. Whilst it carries great potential for innovation, it also means that network participants will need a higher level of engagement and patience [40]. Any sudden shift in the network may trigger a disruption that needs to be managed, often delaying progress however brief, until the change is fully addressed and dealt with by each stakeholder.

A beneficial approach can be to *gradually* build a network wider and wider, with knowledge transfer limited to a small circle at the start, when levels of uncertainties are highest, to a larger group as boundaries become more clear [40]. Concurrently, effective channels of communication, knowledge transfer and also accountabilities can be established that later facilitate building trust in the network quickly by every (new) participant. Equally, the co-creation process itself needs clear structure and project management that can be put in place as the network grows, also to facilitate collaboration between the existing network and new entrants. Often, issues at an individual level reflect larger issues/challenges at higher levels. These need to be captured early and addressed integrally [45]. Also, in innovation, new ideas or knowledge may be created at any level in an organisation: by individuals, within or between departments or even at firm level. Successful organisations seem to leverage off all these levels [46]. A key enabler for this is a collaborative, open communication culture [44]. Where such a culture is missing or not yet fully developed, formal roles like *knowledge brokers* might be installed. These could intervene to stimulate sharing knowledge more openly [40].

13.5 Discussion and Implications for Future Research

The work presented in this paper sought to help building a better understanding of the particular way diversity—at multiple levels of participation—as well as the adoption of co-creation activities and mindsets can help innovation ecosystems to prosper. We find that diversity is in fact vital in furthering creative, novel ideas to be generated in an ecosystem as it allows alternative viewpoints and expertise to be explored, providing opportunities for novel combinations of knowledge to emerge, be varied and (re-) combined in new ways between all stakeholders involved. In fact, a higher level of diversity in an ecosystem, i.e. the mix of stakeholders and their expertise, the higher the chances for innovative solutions to be generated. Equally, however, such ecosystems require more careful management to mitigate different interests, aims and ways of working. Co-creation between committed, open and engaged actors in an ecosystem allows harnessing diversity in a manner that is usually not achievable with more traditional, rather transactional ways of collaborating. It takes time for such a strong connection between actors in an innovation ecosystem to develop, requiring trust, patience and a long-term engagement. Whilst there are several tools to facilitate such a strong connection to grow, ultimately, we see a change in *mindset* towards common goals and benefits of the ecosystems—rather than of the individual—as key prerequisite. And this is ultimately rooted in building longer-term connections that allow trust to build that involved actors have a common benefit in mind.

An ever-accelerating commercial landscape leads innovation ecosystems to become more and more complex: starting with a triple helix—such as the public sector, governments, research institutes but also the private sector—to a quadruple helix, which entails citizens or the media to contribute and communicate knowledge [11, 12, 47]. Thus, the importance of a mindset for co-creation is increased. This means one has to expand the centre of attention to include stakeholders who are not directly impacted by the development to ensure leveraging the full potential of, e.g., a community, business networks, etc. Harnessing such adjacent knowledge and expertise in the best possible manner carries a huge potential to make ecosystems more effective [16]. Yet, how this can be achieved (in different contexts)—in an effective manner—still needs further exploration in research.

Further to our last point, we also expect the number and variety of involved actors to increase as ecosystems evolve in future. This also means, inadvertently, that the roles of involved stakeholders—public and private—will shift. We already see tendencies in the public sector to enlarge their networks (e.g., universities increasingly collaborating nationally and internationally or local governments involving citizens in planning public construction/development projects), in attempt to streamline efforts and ensure that activities cohesively build towards something rather than to compete with one another [30]. Larger societal or technological changes—often inherent to innovation—need the stewardship of the public sector (through legislation or incentives) to 'get off the ground' and involving more actors of an ecosystem ensures a broader public support and more directed actions. Conversely, we see the private sector to gradually, but continuously, change its role beyond their organisational boundaries to directly connect with users, clients or society in general. Companies—not only in the area of design but also engineering—more and more use common citizens for co-creation workshops to ensure alignment with user wants and needs. This has progressed to a point, where the boundaries between non-profit and for-profit organisations become slightly blurred. The emergence of entirely new, more continuously engaging business models, such as product-service systems rather than traditional sales-focused models, is a good example. More continuous, collaborative, 'fair' partnerships with the public sector and civil society, and embracing diverse cultures are likely to accelerate the development of innovation ecosystems [42]. We believe this should also include a stronger link between research institutes, particularly universities, to benefit education of the next generation of employees. Universities can contribute enormous societal value through research, education and generally instilling an innovative spirit in students that benefit innovation ecosystems at multiple levels. This includes for universities to move away from their traditional role as educators of future employees and generators of knowledge to skills and capacity builders benefitting the whole innovation ecosystem. This could also mean rethinking the importance and offerings around lifelong learning.

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Part III
Design Management, Knowledge Management and Product Life Cycle Management

Chapter 14
A Critical Study of Choke Point in Sustainable Recycling of Household Waste in an Assamese Village Setting

Shiva Ji and Ravi Mokashi Punekar

Abstract Stigma around consumable products and impact on local sustainability has led us to choke point. Paper examines household waste disposal into a small pond called Pukhri. After certain intervals, the pond would be dredged out to clean up the pond, which subsequently ended in agricultural fields. Today, other household waste items including material constituting laminated papers, plastics, inorganic waste etc., are being dumped into Pukhri. In order to establish a familiarity with situation, paper discusses imperative need for new order of waste management in village through data assessment and analysis and finding relations between actors, activities, and dependent phenomenon for a sustainable waste management system. It was found that levels of interconnections between various actors are facing blockage and impacts on domestic fowls, fish, and cattle were noticed. The paper elaborates on vernacular system, change in the system and impacts over stakeholders, etc.

14.1 Introduction

The Industrial Revolution has succeeded in its goal of meeting requirements go materials and goods to the masses but has left its widespread devastating effects on environments. The same can be seen in forms of pollutions in cities like Beijing, Mexico City, and New Delhi. The impact of industrialization has also spread to small towns and rural areas now. The solid wastes and chemical compounds have found their ways to enter self-sustainable cycles of elements in rural areas too. This mindless distribution of commodities has of course facilitated but has taken its toll on natural cycles of organic-based lifestyles of people. The advent of material

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culture is called as development but has degraded environment at an exponential scale which has not happened earlier since the last ice ages.

The same was evaluated in the context of village Barduwa, district of Nagaon, in the state of Assam, India. At the social level, a great majority of the people are the Vaishnavites Hindus. Shrimant Shankar devji, the great saint, social reformer, and equalizer of Bhakti movement era was born here. Nestled in the middle of green paddy fields in vast distances, it is at a distance of 15 km from district headquarters of Nagaon. The main occupation of people here is derived from agriculture and allied activities. The society has remained agrarian for centuries and is still prefers the same. The mighty River Brahmaputra flows in the north at a distance of approximately 10 km where there are vegetable growing marshlands. This has the direct bearing on the higher water table in the region. The level of water has given birth to this kind of biosphere. These are the areas from where Barduwa and Dumdumia market receives bumper produce of paddy, vegetables, and mustard etc. The district of Nagaon is in the center of Assam is one of the largest paddy and vegetable producing districts. It has fertile alluvial soil and nearby forested hills. It lies on the main highway from Guwahati to Dibrugarh, Tezpur, and Tinsukia etc.

14.2 The Scenario of Barduwa Village

The village was mapped on aspects of environment, economics, culture, and society. Further it was assessed on finer points such as construction techniques, materials, waste disposal, consumption pattern, food habits, etc., to get performing insight into the place.

14.2.1 Environmental

Building construction techniques: Building structures are single storied and follow simple construction techniques which people undertake themselves for their own use. Shallow foundation footings to install wooden columns in ground for approximately 2′-0″ deep which carries the structural load to the earth. Wall surfaces are broken in sections at sill (2′–6″) and lintel level (6′–6″ to 7′–0″) for accommodating windows and modularity in fabrication. The lightweight of materials creates an earthquake friendly structure which in seismic situations doesn't create much damage and harm to occupants.

Building construction material: Buildings are largely of one story only buildup of bamboo, thatch, straw, timber, jute, and coconut rope. The materials are sourced locally from bamboo bushes and trees, etc. By using simple carpentry tools etc., they get it dressed in shape and size for final fitting in the structure. The materials have almost nil foreign element in them apart from steel nails and fittings. Even regular repairs and maintenance is largely a one-man job and requires little intervention. Sourcing of materials is seasonal as they get harvest of stars and thatch every year in stock which they store for yearlong use. Bamboo and timber come from the felling of trees and sometimes log of coconut tree and beetle nut is also used for use as column, beam, etc. After say, demolition and discard of materials they go back to nature's cycle of decay and disintegration and leave almost no residue which is of prime concern from the point of view of sustainability.

14.2.2 Waste Disposal

Kitchen: People throw kitchen waste in a small pond called Pukhri which is smaller in size and situated right behind the toilets in the backyard of the house. The organic waste disintegrates and decomposes in that and goes back to being manure. After certain intervals, they dredge out the pond to clean it up.

Other household items: There is no provision of garbage collection from village management; hence all waste items constituting papers, plastics, organic waste etc. goes to Pukhri only.

Synthetic (foreign) materials: Polymer-based substances.

Plastic: With advent of new products and specially latest packaging materials made up of plastics and other polymers (to keep liquids and retain items away from atmospheric air) in hygienic condition with a long shelf life, the problem of their collection and disposal has taken a new turn as these villages do not have such systems in place and have remained like this since ages. Mostly people don't know what to do with these and throw them in garbage ponds along with kitchen waste, it doesn't disintegrate on its own and rather hinders with the natural cycle of the pond.

Chemicals: Soft harmful chemicals present in soaps, toiletries, toilet cleaners, insect killers, sprays, and cosmetics are ultimately harmful for microbial life, aquatic life, and amphibians. After the flush from our use, they go to water bodies and a concentration of these harmful chemical occurs resulting in pollution to the chain and irreversible damage to the other life forms.

14.2.3 Economics and Sociocultural Issues

Consumption pattern: People use largely local grains and vegetables, etc. Little use of processed items but it has penetrated in the village and people are unaware to how to deal with it.

Food habits: Mainly consume locally grown fruits such as coconut, Beri, and vegetables as they come cheap and fresh. Little of use of processed items such as biscuits and cakes etc. or only on occasions. Meals comprise fish and chicken and seldom milk as they fulfill neutron requirements from non-vegetarian items. Highly processed items such as pizzas are still far from this place.

Occupation: Hesitation to scale up businesses and enterprises.

14.2.4 Cultural

Festival: Like Holi is celebrated with big fanfare as it coincides with spiritual thoughts and deliveries of Srimant Shakardev ji which has a big following from Vaishnav Hindus of Assam. They congregate in very large numbers on the day of Holi to celebrate.

Prayers: Srimant Shankerdev ji has started Nããm Ghar which is a place of common congregation for open collaboration and dialog. It's a very relevant concept in today's concept to communicate with masses and establish an open bond. It has become more relevant in today's intrinsic society.

Dramatics: These play an important role to integrate people from all sections and delivers thoughts via a strong medium which helps in social uplift. Dramatics helps in keeping people busy and gives a sustainable way of entertainment in comparison with concentrated entertainments like TV etc.

Mobile theaters: These are a very strong medium of moving theatrics across the state of Assam. They entertain, employ artists, preserve cultural heritage, and deliver prevalent message to masses. It's a unique concept on Assam and needs to be preserved and nurtured.

14.2.5 Issues

Infrastructural

Administrative apathy: despite existing railway connection and network, this is almost lying unused. The same can be integrated with the day-to-day life of people, agriculture, traders, suppliers, fisheries, vegetables, producers, etc. Ignorance about potential use of place and its productivity. The place has huge potential interns of agricultural, vegetable and fishery without any promotion or technological intervention. The same sectors can be enhanced further giving organized help and support. The place produces the largest volume of vegetables.

Social

Religious divide between Hindu and Muslim community: Population of Muslim community is growing exponentially and was unable to maintain pace with social, technological, economical, and education growth due to lack of resources and inability to divide among large numbers of family. The attitude of raising many children has resulted in stagnation and deceleration of Muslim families.

Personal: Lack of interest in growth citing pitfalls of fast pace life. Which is in a way right but needs to be addressed with utmost care to not to disturb in their thinking. Lack of interest in growth of family economic activities

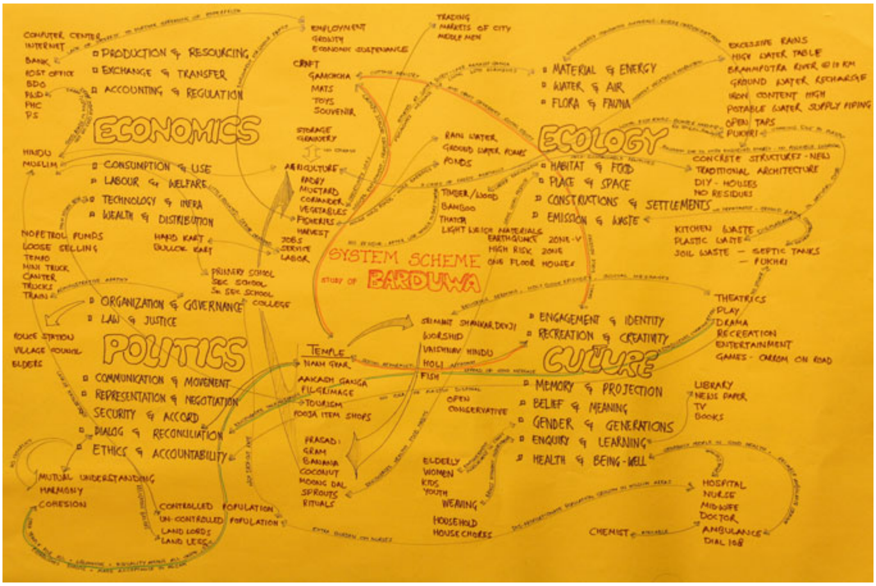

Fig. 14.1 Systems scheme at Barduwa on economics, ecology, politics, and culture poles

14.3 System, Its Domains and Their Interconnectivity

The eight domains of mapped system at village Barduwa are agriculture, education, health, cottage industry, habitat, water, sanitation, and transport. The interconnection among all 8 was explored and 3 issues were fore identified. The issues of product life cycle, waste disposal, and cultural propagation were found to be taken up urgently.

Further a systemic model map of Barduwa village was drawn on four poles of economics, ecology, politics, and culture. These issues could give an objective intervention point to the system of Barduwa. It bears an influence over the policy decisions and implementation strategies for the place (Fig. 14.1).

The system was divided into eight groups which became the eight nodes and further classified into four poles of economics, ecology, politics, and culture. The internal points within poles were marked and their interrelationships were established. Further a unit habitat was chosen to assess the points and help of LeNS tool was taken, assessment is given below.

14.4 Synthesis Index

An analysis was carried out with help of LeNS tool to assess impacts on surroundings, people and the system of place. LeNS is Learning Network on Sustainability, it is an EU-funded multi-institute research project which works toward understanding of sustainability-related studies. It has undertaken several case studies across globe and has brought experts and students on the common platform. It has developed certain tools to carry out mapping, assessment, and evaluation of sustainability. Paper assesses sustainability of designs from village of Barduwa using Syntheis Index tool given by LeNS. LeNS provides comprehensive set of evaluation criteria which may be used in qualitative research of this kind and draw inferences.

Learning Network on Sustainability (LeNS) provided tool used here to assess impacts of various elements of structure (combination of resultant ideas and inputs to form a theory or system): On a scale of (YES | PARTIALLY | NO) /100:

Priority high (A)
Choosing low impact resources and processes:

- Reducing toxicity and harmfulness of materials 73% 18% 9%;
- Reducing energy resources toxicity and harmfulness 100% 0% 0%;
- Optimizing biocompatibility and conservation of materials 67% 33% 0%;
- Optimizing biocompatibility and conservation of energetic resources 0% 33% 67%.

Conclusion: Resources used are less toxic in nature, require biocompatibility.
Optimizing product life:

- Designing an appropriate life span 25% 57% 14%;
- Designing reliability 33% 67% 0%;
- Facilitating renewability and adaptability 29% 29% 43%;
- Simplifying maintenance 11% 11% 78%;
- Simplifying repair 0% 29% 71%;
- Simplifying reuse 11% 22% 67%.

Conclusion: High to average product life, needs to be designed for maintenance, and repair.

Priority medium (M)
Extending material life:

- Adopting a cascade approach 50% 50% 0%;
- Adopting high recyclable materials 43% 43% 14%;
- Simplifying collection and transportation after usage 33% 44% 22%;
- Identifying the materials 17% 0% 83%;
- Minimizing the number of incompatible materials 80% 20% 0%;
- Simplifying cleaning 20% 30% 50%;
- Simplifying composting 75% 25% 0%;
- Simplifying combustion 100% 0% 0%.

Conclusion: Recyclable, homogenous but combustible materials used.
Simplifying disassembly:

- General architecture 27% 18% 55%;

- Shape of parts and components 57% 43% 0%;
- Shape and accessibility of joints 0% 38% 63%;
- Using reversible joints 0% 0% 100%;
- Using easily opening permanent joints 13% 13% 75%;
- Predicting technologies and elements for destructive disassembly 0% 14% 86%.

Conclusion: Architecture, parts and components, shapes and joint detailing require revision.

Low (B)
Minimizing resources:

- Minimizing the material content of a product 38% 25% 38%;
- Minimizing scraps and waste 33% 33% 33%;
- Minimizing the packaging 25% 50% 25%;
- Choosing the most efficient material consumption system 22% 56% 22%;
- Adopting flexible material consumption systems 0% 0% 100%;
- Minimizing material consumption in product design 0% 25% 75%;
- Optimizing energy consumption for pre-production and production 14% 21% 64%;
- Minimizing transportation and storage consumptions 30% 40% 30%;
- Choosing the most efficient energy resources consumption systems 33% 8% 58%;
- Adopting flexible energy consumption systems 20% 20% 60%;
- Minimizing energy consumption in product design 0% 0% 100%.

Conclusion: Resource use requires some justification, and requires flexible material use techniques.

Overall Conclusion: The results confirm areas for improvement: Biocompatibility, maintenance and repair, architecture, parts—components, shapes and joints etc., require design and detailing intervention. The items which are proving to be the choking agents are the main targets for biocompatibility such as plastics, coated plastics; this intrusion is breaking the closing of the cycle. In fact, the same is the case almost everywhere in general but the same is validated on the ground. Maintenance and repair would elongate the life span of habitats and may reduce resource requirements.

LCA Tool used: The LCA was carried out using tool for the “design of low impact for the environment” by Laboratory of Design for Sustainability (De.SOS) by Carlo Proserpio and Prof. Carlo Vezzoli from Durando 10 Edificio 7 (POLIteca) 20158 Milano, Italy under an EU-funded research project.

14.5 Conclusion

A field base study of sustainability in a rural context to check on household waste disposal was carried out to get to know the chokepoints in the cycle of conventional practices. A systemic analysis using LCA tools shows resource materials used in the habitat design of the chosen system were not toxic in nature but require biocompatibility in decomposition. Some materials were found with chemical treatment like powder coatings and complex layering of paper with plastics, alloys which are hard to galvanize, and some plastics with very long duration for decomposition, etc., which were acting as choke point in the smooth functioning of the system. Further longevity, repair, and maintenance were the issues found which are in need to be addressed. Complex material systems require handling and maintenance to remain working for longer times. These issues should be resolved at local level itself to minimize on indirect emissions. Some materials were found to be recyclable and homogenous in consistency such as iron/galvanized iron/tin in metals, timber/wood, and bamboo/reed, but combustibility was an issue. In cases of fire, it is hazardous to live in all combustible material houses. Joint detailing was also in need of revision keeping in mind component design and maintenance, etc., and flexibility in use. These were the findings of this field-based study which found some points which are behaving to choke the system and should be resolved to maintain the spontaneous nature of sustainability in the chosen system. Further, the study can be improved by conducting similar field-based case studies at different places to check on the phenomenon in other places as well. It may help in establishing the commonality and generalization of the results of the study.

14.6 Summary

The place has spiritual linkage and people of this place have shown remarkable empathy and humility in maintaining social peace and harmony for many generations. It has been running for centuries and has derived its own ways of living. Further with the advent of industrialized solutions in everyday life, some points have become resistive in the system and are resulting into blocking the system as minute levels. Wastewater cycle needs to be checked and corrected of foreign elements like plastic. Soil wastewater needs to be treated to check water contamination, and education sector needs to work toward higher education side to attract students from nearby areas who go to city for higher studies.

A better way of designing houses is required which can adopt from traditional Assam type architecture and incorporates the same in contemporary construction methods which suits the people's requirement otherwise it's on the verge of being left out in the race of being left out to the concrete mortar structures. The vernacular Assam-type house provides with earthquake protection, sustainable local materials, and self-made techniques, completes the material life cycle, etc. It has survived all the highs and lows of environment and social domains and has potential to do so if can be redesigned for current times. The place is significant on the map of Assam in terms of tourism, agriculture, and crafts. The same can be designed, developed, and promoted as sustainable—Cultural Hub of Assam.

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Chapter 15
Application of MDM for Scheduling Iteration in Construction Projects

J. Uma Maheswari, S. P. Sreenivas Padala, Srijan Sharma and Suchita Sariyal

Abstract Design phase of any construction project is associated with multiple information exchanges among and across several entities such as teams, components, deliverables, or parameters. When these information exchanges occur along the cycles/loops, it is termed as iteration. In general, the information exchanges traversing within and across several entities in any direction throughout the design phase were referred to various ways such as interdependent, overlaps, two-way information exchanges. In this study, these information exchanges were referred to as interdependent or beelines. If this interdependency and iteration are not identified early and planned properly, it can lead to unnecessary changes which ultimately results in time and cost overruns. To date, researchers had identified the beeline diagramming method (BDM) as the potential method to model the beelines. Also, multiple domain matrix (MDM) is a powerful emerging methodology for capturing iterations across multiple entities. In the present study, an attempt is made to utilize the potential features of MDM in modeling and scheduling beelines in construction projects. To demonstrate the proposed concept, the design of underground metro construction project data was used. The preliminary results of this study were found noteworthy, and it was observed that the MDM has adequate potential to model beelines.

15.1 Introduction

The design process is complex due to several multiple information exchanges within and across the entities. Entity is a generic term used to refer either teams, components, deliverables, activities, or parameters [1]. These information

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exchanges can be classified into four types of relationships such as independent, dependent, semi-independent, and interdependent [2, 3]. Here, interdependent entities are the one which requires information from both the predecessor and the successor as shown in Fig. 15.1a, b. To distinguish the figures, Fig. 15.1b is referred to as multiple two-way information exchanges or beelines or divisive overlapping, and on the other hand, the simplified version of beelines is referred to as the interdependency as seen in Fig. 15.1a. Beelines are defined as the shortest straight lines between any two entities several times in any direction, i.e., bidirectional/two-way multiple linkages [4]. Krishnan et al. [5] have identified iterative, distributive, divisive, and preemptive as the four overlapping solutions for rework occurrence and its impact. Here, iterative overlapping as shown in Fig. 15.1c is challenging in any construction project. The beelines in iterative overlapping may prompt for assumptions. If these assumptions are not accurate, revisions will occur which are termed as iterations as shown in Fig. 15.1c. Failure to model the iterations appropriately in this overlapping type may result in ad hoc rework and chaos.

Several techniques are developed that can aid in modeling multiple information exchanges or interdependencies or beelines in the construction projects. The PDM is a conventional technique that can model single information flow using the four types of relationships and lead–lag concept [6]. On the other hand, continuous relationships represented multiple information exchanges, but it is limited to adequate research investigation and practical application [7]. The beeline diagramming method (BDM) [4] which is an extension of PDM is efficient in representing multiple two-way information exchanges in construction projects. BDM uses concept of beelines. Mujumdar and Maheswari [8] explored BDM for the first time in the design phase of highway construction projects and concluded that BDM is a

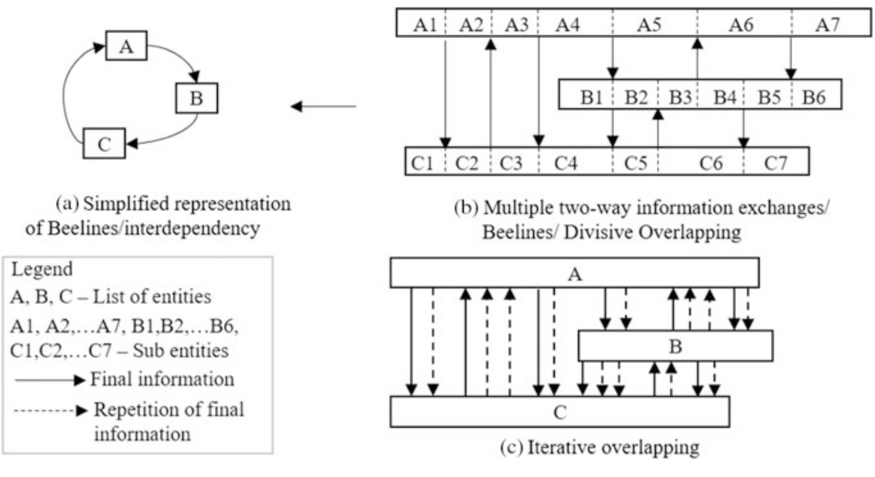

Fig. 15.1 Types of dependencies

potential method to model multiple two-way information exchanges or beelines or divisive overlapping.

Design structure matrix (DSM) [9] came into existence to overcome the limitations of the graph-based methods. DSM can model iterations in any single entity. So far, very few researchers had explored the iterations in design phase of construction projects [10–12]. Multiple domain matrix (MDM) is an emerging matrix-based methodology which is used to capture relationships among multiple entities holistically [13]. Few researchers explored the applications of the MDM in the construction sector [14–16]. These investigations reveal that MDM has a lot more potential as a scheduling technique.

The objective of the present study is to model beelines in MDM in construction projects. The proposed concept is developed based on BDM and MDM method. BDM can represent and schedule beelines or interdependency, and MDM can model and schedule iterations. The proposed concept is illustrated using an underground metro case study, and the results are discussed.

15.2 Proposed Concept and Methodology

To illustrate the proposed concept, a hypothetical case with two entity types—*A* and *P*—is considered as shown in Fig. 15.2. In this example, *A* and *P* can be assumed as activities and parameters, *A*1, *A*2, and *A*3 are the list of entity *A*, and *P*0, *P*1, *P*2… *P*5 are the milestone parameters of entity *A*. Initially, BDM is developed and the information exchanges among the activities are expressed as the conventional 'N_1–N_2' type as shown in Fig. 15.2a (interested readers can refer to [4, 8] for BDM). For instance, in Fig. 15.2a, parameter *P*1 is communicated to *A*3 when *A*1 and *A*3 had completed 3 and 2 days, respectively. This is represented using the linkage '3–2' (N–N), and the other linkages can be read similarly. BDM is not critical in modeling and estimating iterative overlaps. However, BDM can reduce errors in formulating/developing the MDM. Additionally, it can also be used for representing the entity relationships and reworks holistically. Next, MDM skeleton can be developed with the list of entities as shown in Fig. 15.2b. The parameters released by activities and required by activities are captured in Domain Mapping Matrices (DMMs) along with their durations through N_1–N_2 linkages of BDM as shown in Fig. 15.2b. Other parts of MDM are populated as usual (interested readers can refer to [17] for MDM population).

The methodology for the proposed concept is shown in Fig. 15.3. In this figure, block 1 provides steps for structured data capture in MDM using BDM and block 2 focuses on the scheduling entities in MDM. To bring the probabilistic repetition of the entities, rework probability [18] is used. The 'X' marks inside iteration block on off-diagonal cells in MDM as shown in Fig. 15.2b should replace by rework probability values which lies between 0 and 1, where 0 represent no repetition and 1 represents repetition at every instance [18].

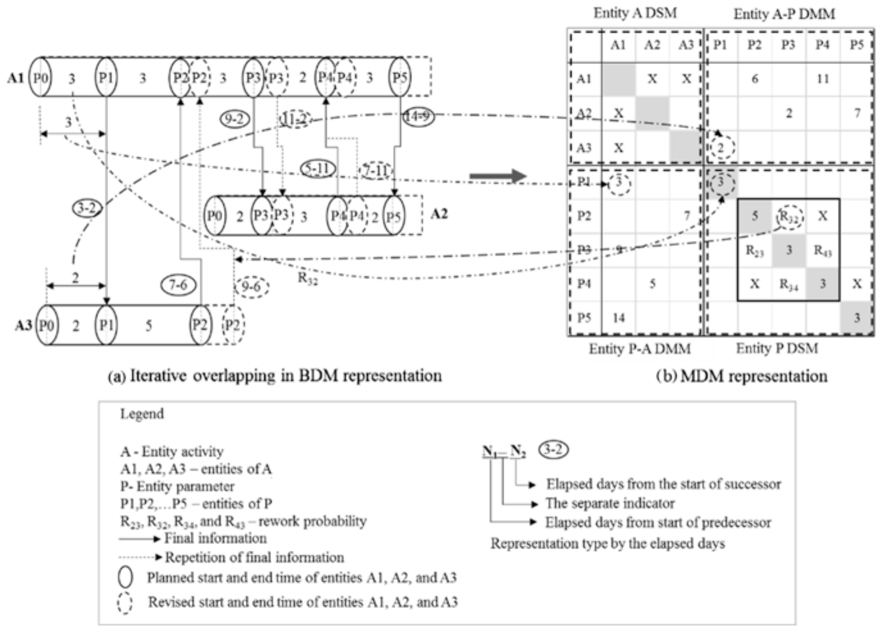

Fig. 15.2 BDM–MDM integrated concept

15.3 Case Study and Results

The proposed methodology is demonstrated using design data of underground metro construction project. The scope of the application was on finishing stage of the underground metro project which includes architectural finishes and services. Data were collected through several modes [19] such as document reviews (design manuals, change orders), interviews (semi-structured with design experts), physical observation (client meetings, site visits), archival records (past project performance), and artifacts. Two types of data—qualitative such as dependencies between entities and quantitative which includes the duration of entities, release and require the time of entities were obtained. In this case study, three entities such as teams, packages, and deliverables were considered for analysis as shown in Fig. 15.4. Initially, BDM network was developed for two scenarios—(a) teams and deliverables, and (b) packages and deliverables as seen in Figs. 15.5 and 15.6, respectively.

The complete MDM for all three entities is shown in Fig. 15.7. From the figure, it can be observed that MDM enables holistic visualization of all the entities and their relationships which can help in minimizing mistakes and errors. Initially, MDM skeleton structure with no relationships is formed. Then, the relationship of any entity to the last entity, i.e., parameters, is filled. Further, the duration of release and require information of deliverables from teams and packages was populated in

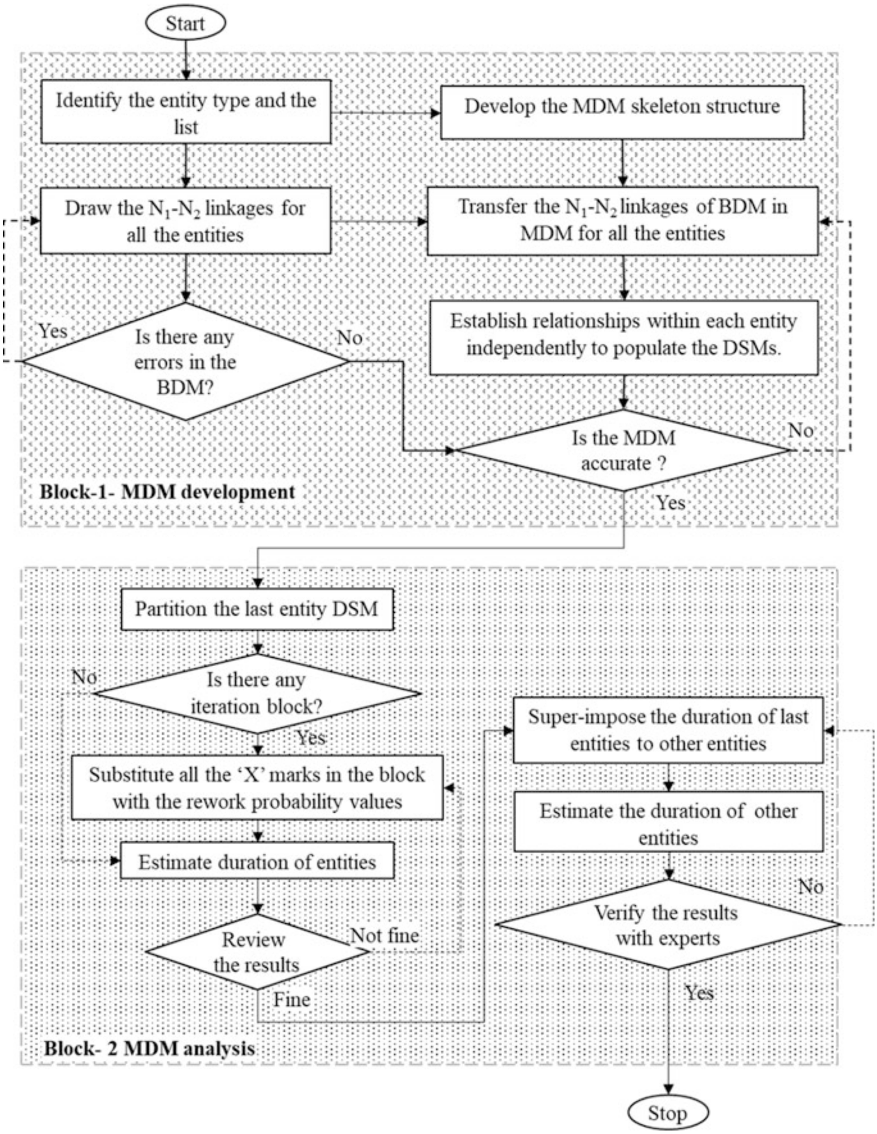

Fig. 15.3 Solution methodology

respective DMMs. This population is done by transferring the N_1 values of the BDM into the corresponding cells of MDM. For instance, the information on deliverable–team DMM and team–deliverable DMM of MDM is obtained from BDM automatically as shown in Fig. 15.7. Subsequently, the relationships between the deliverables are gathered through experts through discussions to populate deliverable DSM. As can see in Fig. 15.7, there is no iteration block in deliverable

Teams	Deliverables
SD (Structural Design Team)	SD1 (Preliminary Design and Design Reports)
EM (Electrical and Mechanical Team)	SD2 (Definitive Design and Design Reports)
CO (Contractor)	SD3 (Construction Reference Drawings for cutouts)
Packages	EM1 (Foundation layout and sizes)
PS1 (Tunneling and Passage Drawings)	EM2 (Access for Flooring)
PS2 (Station Detail Drawings)	EM3 (Access for Finishing)
PE1 (Services Schematics)	EM4 (Handover to client)
PE2 (Installation and Testing)	CO1 (Architectural Drawings)
PC1 (Management and Civil works)	CO2 (Access for First fix items)
PC2 (Masonry & Finishing works)	CO3 (Access for Second fix items)
	CO4 (Integrated testing and commissioning)
	CO5 (Handover to client)

Fig. 15.4 Chosen entities of the underground metro construction project

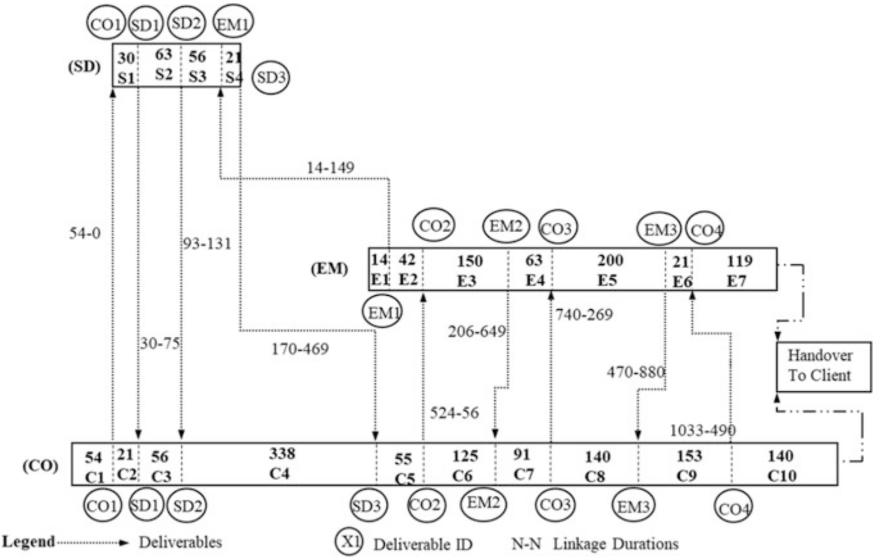

Fig. 15.5 BDM network for entity—teams and deliverables

DSM. Iteration that exists in the team and package DSM can aid the design team to plan for necessary changes in the design. Moreover, it also aids to visualize the feedbacks across several entities. Since the duration of team and packages is required to estimate from deliverables, iteration is not considered. Thus, the duration of teams and packages is obtained by superimposing the parameter duration values onto the corresponding entities as shown in Figs. 15.8 and 15.9.

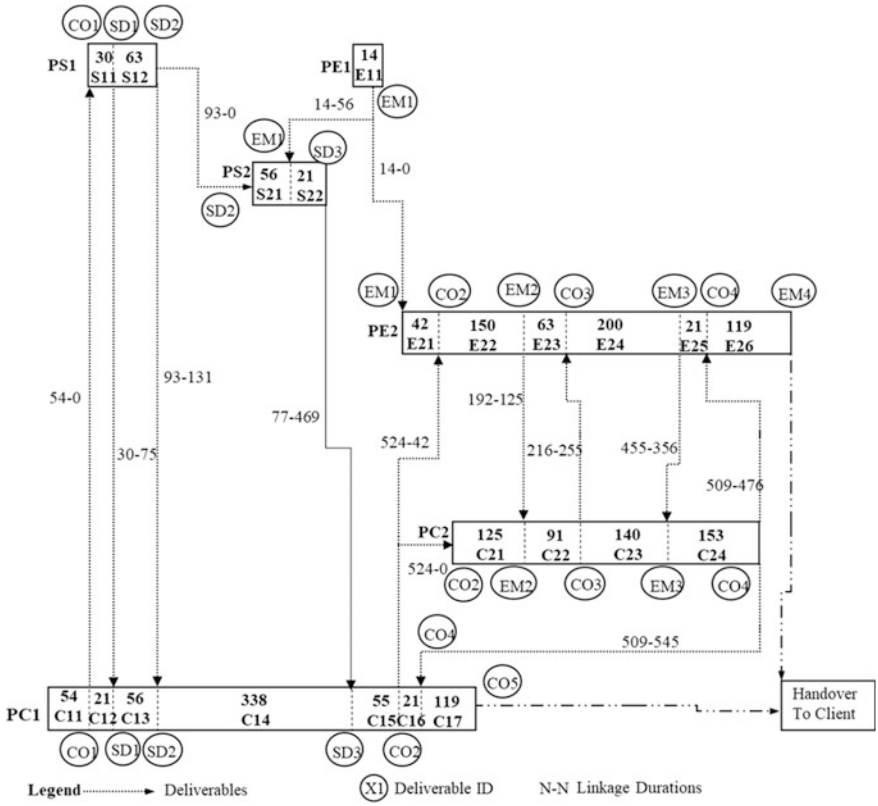

Fig. 15.6 BDM network for entity—packages and deliverables

15.4 Conclusions

This study set out to develop an MDM framework to model and schedule beelines. Planning for the design process in a construction project is more complex, especially with the participation of numerous entities such as teams, parameters, components, and deliverables that have beelines. Representing these beelines in BDM and their analysis involving all the entity relationships is a challenging task as each analysis has to be separate as elaborated in the case study. By using MDM, the entities can be grouped together which can trigger for more accurate information. Henceforth, by developing MDM for beelines, multiple BDMs can be generated at ease. In this study, the data capture on BDM is assumed to be accurate. However, errors in BDM can be transferred to MDM and can give erroneous results. There is a need for systematic methodology to capture accurate entity data in BDM.

	SD	EM	CO	PS1	PS2	PE1	PE2	PC1	PC2	SD1	SD2	SD3	EM1	EM2	EM3	EM4	CO1	CO2	CO3	CO4	CO5
SD		X	X			X		X					149				0				
EM			X					X	X									56	269	490	
CO	X	X		X	X		X			75	131	469		649	880						
PS1	X							X									0				
PS2	X			X		X					0		56								
PE1		X																			
PE2		X				X		X	X				0					42	255	476	
PC1			X	X	X				X	75	131	469								545	
PC2			X				X	X						125	356			0			
SD1	30			30						30											
SD2	93			93						X	63										
SD3	170				77						X	77									
EM1		14				14							14								
EM2		206					192						X	192							
EM3		469					455						X	X	263						
EM4		609					595						X		X	140					
CO1			54					54									54				
CO2			524					524			X	X					X	470			
CO3			740						216		X	X						X	216		
CO4			1033						509		X	X							X	293	
CO5			1173					664									X			X	140

Fig. 15.7 MDM of the underground metro construction project

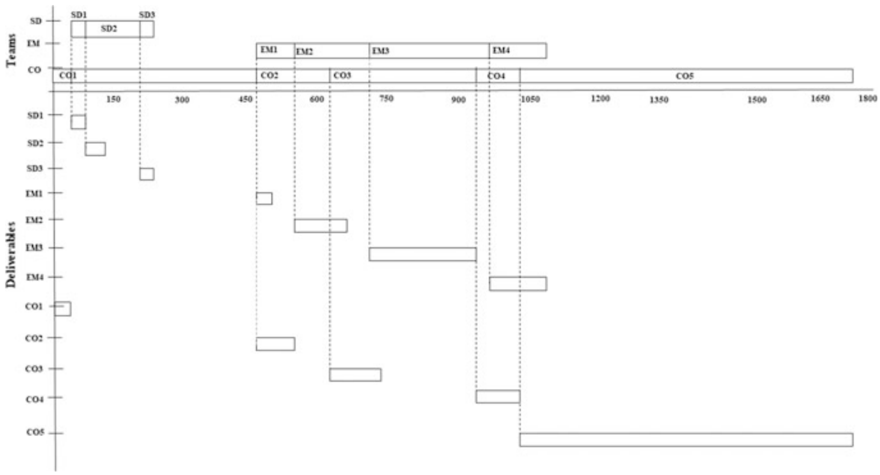

Fig. 15.8 Teams and deliverables' schedule—underground metro construction project

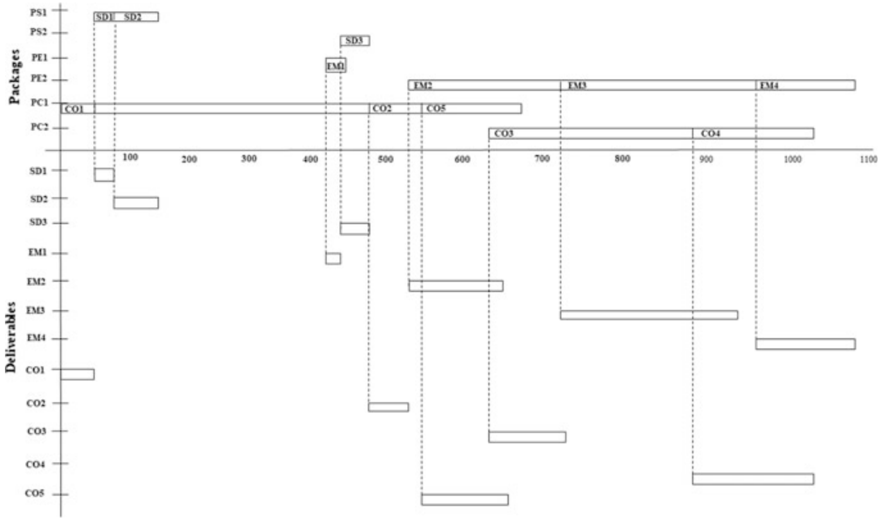

Fig. 15.9 Packages and deliverables' schedule—underground metro construction project

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Chapter 16
Design Management Intervention in Product–Service System of Water Supply

Sachin Shivaji Jadhav, Pratul Ch. Kalita and Amarendra Kumar Das

Abstract Strategic design management in product–service system in the context of water supply is the prime focus of the study. The study formulates strategic relationships of product and service components by considering life cycle perspective of water supply system. The process diagram of the water supply system of the community was developed on the basis of initial system study. Personal interview was conducted with the people in maintenance section of the water supply system to gather information about overall water supply system from the source to the end user. It has been observed that the water supply system involves several small and medium firms that provide materials and manpower to the system. Quality function deployment (QFD) method is used to identify and meet customer's requirements. Strategic design thinking in integrating of products and service design could improve the uninterrupted supply of clean water. The framework developed for product–service system study and the methodology adopted in the study may provide new insights into the field of design education and research.

16.1 Introduction

Product–service system as a business model for sustainability has been discussed over the past two decades [1]. Integrating products and service is a growing trend among companies in today's globally competitive business environment [2]. A product–service system design approach is required for essential community-level services like water supply system [3]. The capability of storing,

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managing, and analyzing the large data set of water supply requires mapping and use of multi-support information system. The renovation of water treatment technologies and distribution networks could improve the water supply situation, but this requires financial resources and changes in water management operations and maintenance [4]. Service management researchers are interested in studying clean technologies, as an innovative idea for water sector [5]. The integration of the service provider, stakeholder, contractor, and the community, which is common in product service system offerings since they comprise a network of actors to contribute better management of the system. There is a lack of research on business models in water sector.

The objective of this study is to understand how PSS offerings are collective, such as life cycle maintenance of water supply system in a community. The study involved detailing of product and service components involved in water supply system and mapping of product–service components of water treatment plant, cooler, and purifier. Quality function deployment method was applied to prioritize products/service purifier components. The research presented here can contribute to the field of application of design methods, viz. product–service life cycle and quality function deployment in designing product–service system.

16.2 Methodology

Research hypothesis has been formulated that 'product–service system design thinking for strategic mapping of various product–service components of water supply system in a community can evolve better design management strategy for uninterrupted supply of clean water.' In order to find the attributes of products and services, a case-based research is considered on the basis of life cycle perspective of water supply [6]. Information was obtained through semi-structured interview (lasting 25–35 min). The respondents were supervisor of VA Tech Wabag Ltd. at water treatment plant, two assistant engineers from maintenance section and a junior assistant who looks after repair and defects of cooler and water purifier. For better understanding, observation and ethnography were also conducted at water treatment plant, water coolers, and water purifier. On the basis of the data gathered, a process diagram was developed for water supply system depicting the flow from source to end user. The entire process flow was then divided into three parts, viz. (i) source to water treatment plant, (ii) treatment plant to reservoir plant, and (iii) reservoir to end user. The detailed system study was conducted in each of the aforesaid segments of the process. Detailed process diagrams of all the segments were generated. Interactive sessions were conducted with the suppliers, engineers, and workers involved in each part of the entire system. Product and service components in all the stages of the segmented processes were identified. A matrix was developed considering product–service components of the system. The product attributes are: product, spares, and availability. The service attributes are regular maintenance, preventive maintenance, breakdown maintenance, physical facilities, people, and contract/outsourcing. Various issues of internal and external customer of the system were also taken into consideration. Structured questionnaire was administered, and personal interview was conducted to collect life cycle perspective of each product and service components of water supply.

16.3 Water Supply System—Overview

Water supply system is a system of technical elements that supply water from its source to the users that is being managed by one legal entity (usually a public service provider) and operates mainly as an independent system hydraulically separated from other systems [7]. Water supply system, in general, has various product and service components. The study was conducted in the existing water supply at Indian Institute of Technology Guwahati located in the state of Assam, India. Preliminary studies from the field visits provided an overview of water supply system. The entire system was divided into sub-categories for identification of involvement of product and service components, type of water treatment schemes, capacity, and filtration method. Edraw software was used for describing the product–service system concept [8]. The process diagrams generated were followed by mapping of product–service system components of water supply system. This exercise provided a complete and clear overview of product–service issues of system under study. It also identified the potential failure points. It further helped to determine the role and level of participation of customers and various stakeholders in the system. It explored the various factors customers and other stakeholders come in touch. It also showed areas of interactions, levels, and stresses of interaction between different actors of the system.

The flow of water and interaction of maintenance department with contractor, supplier, and consumers is shown in Fig. 16.1. Water is extracted from the Brahmaputra River through centrifugal pumps located in pump house to the water treatment plant. Filtration of raw water in water treatment plant is carried out by VA Tech Wabag Ltd. on contract basis structured by maintenance department. Filtered water is then delivered at three separate reservoir tanks, each of capacity 3 lakh liters. One is located over the hill at a distance of 500 m, and other two are located at approximately 1050 m from the treatment plant. From the reservoir tanks, filtered water is supplied to overhead tank of respective groups, viz. establishments, communities, and buildings. These groups are denoted as Group A, Group B, and Group C in Fig. 16.1. Water supply has been provided regularly to meet various functional water needs of the IIT Guwahati Community, viz. drinking, cooking, bathing, washing, flushing of toilets, gardening, centralized AC plant, institutional needs for constructions, and flushing of sewers. Supervisors at each group are appointed for smooth operation and operational maintenance such as plumbing, sanitation, and leakage. Preventative maintenance is carried out for replacement of cooler and purifier parts along with preventive inventory management.

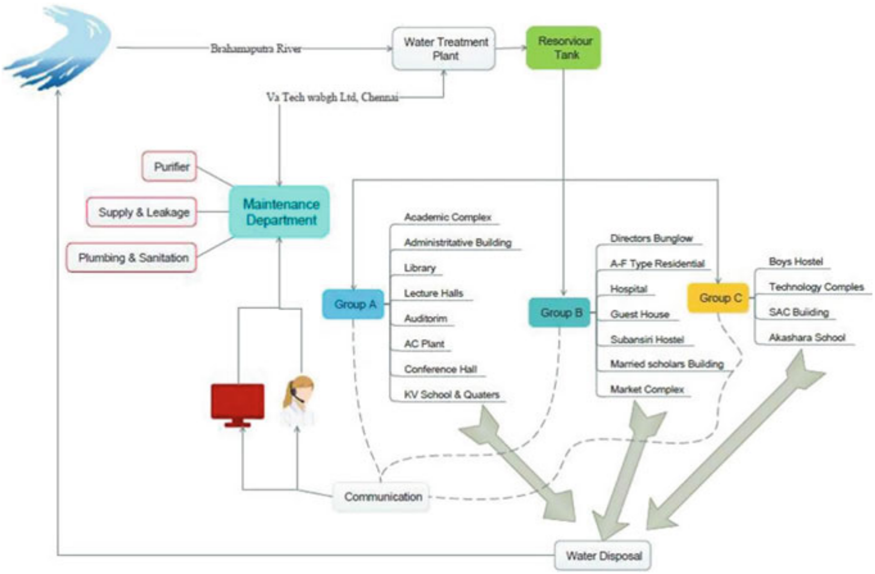


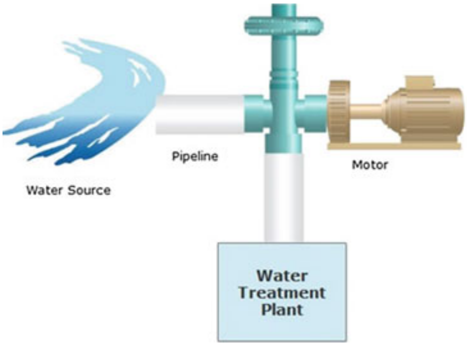
Fig. 16.1 Water supply system—overview

16.4 Results and Discussion

The strategic relationships between product and service components were analyzed in three parts. The first part is from the source to the water treatment plant. The second part is the water treatment plant to the reservoir tank. The third part is the reservoir tank to the end user. In each part, product and service components were identified and mapped. Following is the description of product–service system components and their mappings.

16.4.1 Source to Water Treatment Plant: Product–Service System

In this part, the major products are motor, pump, valves, pipeline including various pipe fittings, viz. elbow, flange, and couplings. Service components are motor winding, replacements of bearings, gear differentials, cleaning and lubrication, leakage maintenance of the pipeline. Figure 16.2 shows details of product and service components of this part.

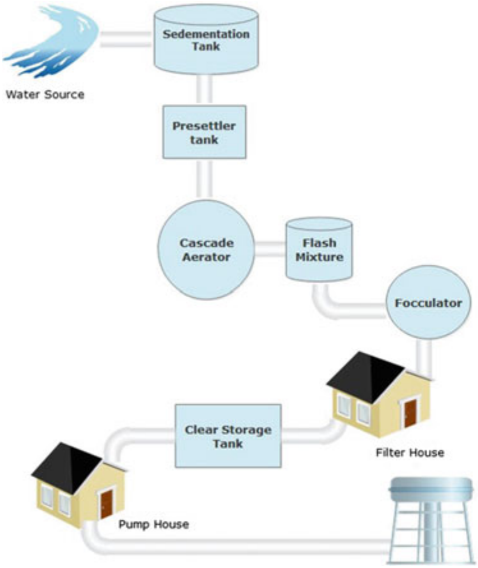


Particulars	Details
Motor	• 2 No. running 1 No. standby • KSB make: Mega Gc 100-200 model • Capacity: 175m³/hr , 45 kW, 60Hp • maximum Current: 72 amp • Voltage: 440V
Pipeline	• Diameter : 250 mm • length : 550 m • Material : Ductile
Service Components	• Pump : 2 years life KSB make • Valve : 18 months KVMC make

Fig. 16.2 Product–service system—source to water treatment plant

16.4.2 *Water Treatment Plant to Reservoir Tank: Product–Service System*

In this part, the product components are alum, motor, valves, pumps, shaft sleeves, bearings, toothed pinion, gears, chlorinator, etc. Service components are cleaning of algae, replacement of gear system, and breakdown maintenance of shafts. Figure 16.3 depicts the product–service system components in the filtration process of water treatment plant.



Section	Products	Services
Sedementation Tank	----	• Cleaning • Capacity 7.2 lakh liters
Presettler Tank	----	• Cleaning algae • manual cleaning
Cascade Aerator	----	• Cleaning algae • manual cleaning
Flash Mixture	• Alum dosage • Motor	• Bearings • Gear system • Toothed pinion
Focculator	• Valves • motor	----
Filter House	• Valves • Core sand • Gravels	• Cleaning filter bed
Pump House	• Pumps • Shaft protection sleep	• Bearings

Fig. 16.3 Product–service system—water treatment plant to reservoir tank

16.4.3 Reservoir Tank to End User: Product–Service System

In this part, the product components are pipeline including various pipe fittings, cooler, purifier, and push tap. The service components are leakage prevention and corrosion maintenance of pipeline, cleaning of overhead tanks at each establishment, preventive and breakdown maintenance of cooler and purifier. Figure 16.4 depicts the product and service components of reservoir tank to end-user part.

16.4.4 Mapping of Product–Service Components of Water Treatment Plant

The mapping was done for the water treatment plant considering the factors linked with product–service system of each section. Factors considered were service frequency, time for service, number of workers, lead for spare, shutdown during service, and skill required.

Table 16.1 shows the detailed mapping of product–service system. It was found that the flash mixture section is critical. It requires 24 h for service with high-skilled manpower. It also has 4 days lead time for spares. It was also observed that due to breakdown of the motor, flash mixture operation was carried out manually. It has been observed that flocculator section is also moderately critical. Therefore, a better product–service system design strategy is required in the aforesaid sections.

Following are the general observations made over the water treatment plant. Communication to any problems related to water is done through mail or telephonic conversation. People are working round the clock on different shifts to ensure smooth operation. The raw water contamination varies according to monsoon and non-monsoon seasons, measured based on turbidity. Whenever the turbidity is low, alum dosing is less. Although the water passes through units such as flocculators and settling tanks before passes through backwash sand filters. The cleaning of spade in pre-settler tank was manually carried out due to breakdown of the motor. Alum bricks are made into solution in chemical house and added to flash mixture. Further mixing has to be done by the motor. But it was observed that mixing of alum in flash mixture was done manually. Record for consumption of alum on daily

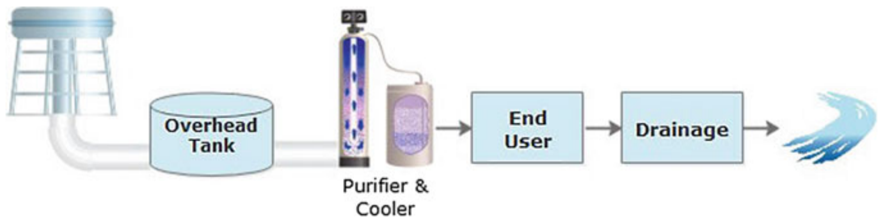


Fig. 16.4 Product–service system—reservoir tank to end user

Table 16.1 Products and service components of water treatment plant

Sections	Product–service components	Service frequency (in months)	Time for service (in hrs.)	No. of workers	Lead for spare (in days)	Shut down
Sedimentation tank	Cleaning spade	6	56	8	–	Yes
Pre-settler tank	Cleaning spade	6	4	3	–	Yes
Aerator	Cleaning algae	1	1	3	–	Yes
Flash mixture	Motor	4	8	2	4	Yes
Flocculator	cleaning	6	8	8	–	Yes
Filter house	Valves	12	40	5	7	No
	Filter bed	1	1	1	–	
Clear storage tank	Cleaning	6	8	8	–	Yes
Pump house	Shaft	48	16	3	90	Yes
	Sleep	24	16	3	90	
	Chlorinator	6	8	2	1	

basis is maintained properly. It was also observed that most of the products related to motor were worn out. Spares were not supplied on time. Cleaning of filter house has to be done every 6 months. It was observed that it was not cleaned properly on regular basis. This problem has occurred due to non-availability of third-party service provider. Our recommendation in this aspect is for application of system thinking to evolve a product–service system design strategy. Mapping of the product–service system discussed in this study can help in formulating an effective management strategy considering all the stakeholders and components of product–service system of water treatment plant.

16.4.5 Mapping of Product–Service Components of Cooler and Purifier

The mapping was done for water cooler and purifier section considering the factors linked with product–service system of each section. Table 16.2 depicts the mapping of product–service system components of cooler and purifier. It was observed that in most of the product–service components shutdown is necessary during service. It was also observed that it requires high-skilled manpower. Therefore, proper preventive maintenance policies are to be framed. It was also observed that records on service components for purifier and cooler were not maintained properly by the contractor. It was difficult to track for the specific product–service components placed on the individual purifier or cooler. Therefore, it is recommended to design a

Table 16.2 Product–service components of cooler and purifier

	Product–service components	Service frequency (in months)	Time for service (in hrs.)	Shutdown	No. of workers
Cooler	Capacitor	Depends on voltage	0.5	Yes	2
	Refrigerant	If leakage	3	Yes	2
	Fan motor	4 months	1.5	Yes	2
	Thermostat	4–5 years	0.5	Yes	2
	Push tap	Users	0.25	No	1
Purifier	RO membrane	1–2 years	1	Yes	2
	Cotton spun	3 months	0.67	Yes	2
	Filter candle	3 months	2	No	2
	Solenoid valves	6 months	1.5	Yes	2
	12 V PCB	Depends on voltage	1.5	Yes	2

computerized information system to streamline the preventive maintenance including optimization of inventory and schedule. From Table 16.2, attributes are: service frequency, time for service, shutdown during service, and number of workers.

Inventory and high skill are the characteristics for majority of product–service components. To provide necessary service high-skilled and a semiskilled labor is must in most of the situations. The maximum time required is 3 h to replace refrigerant, and the minimum time required is 0.25 h to replace push tap. Service frequency for these two products is unlikely (if leakage). Capacitor and 12 V PCB depend on voltage variations to get replaced. RO membrane and thermostat require more than a year for service frequency, and time required to replace product is 0.5–1 h. Therefore, purifier product is selected for improvising service and quality of product. Selecting purifier product depends on two reasons. First as service frequency to be minimized and is average compared to products of cooler. Second as time required to replace products of purifier consumes more time associated with products of cooler.

16.5 Quality Function Deployment (QFD)—Purifier

QFD is a popular quality method that is developed in the 1960s and the 1970s to address design quality challenges to meet better customers' expectations. QFD is a proven technique that is able to translate customer's requirements into design requirements [9]. Akao [10] defines QFD as a method for defining design qualities that are in keeping with customer expectations and then translating the customers' requirements into design targets and critical quality assurance points that can be used through production–service development.

A. Martins and E. M. Aspinwall has experimented with QFD method in development of product, processes and service together [11]. Knowledge management and QFD approach were employed to know customers' needs in a new product design development project in a mineral water company [12]. We also found a very interesting application of QFD in selection processes for supplier evaluation in a pharmaceutical company [13]. Effectively to meet customer's requirements, it is required to review the voice of the customer throughout the production–service development. The customer's requirements for water purifier include, viz. product components' longer life, spare parts size should fit correct, durability, use of better material, convenient packaging, less cost, no leakage, and provide installation services. The customer assigned a weight indicating relative importance of each demand. The ratings for the weight are among 1 to 5, with 5 being the most important demand. The quality characteristic for water purifier is classified into two parts. First part is product-related technical measures, viz. RO membrane, cotton spun, filter candle, solenoid valve, and 12 V PCB. Second part is

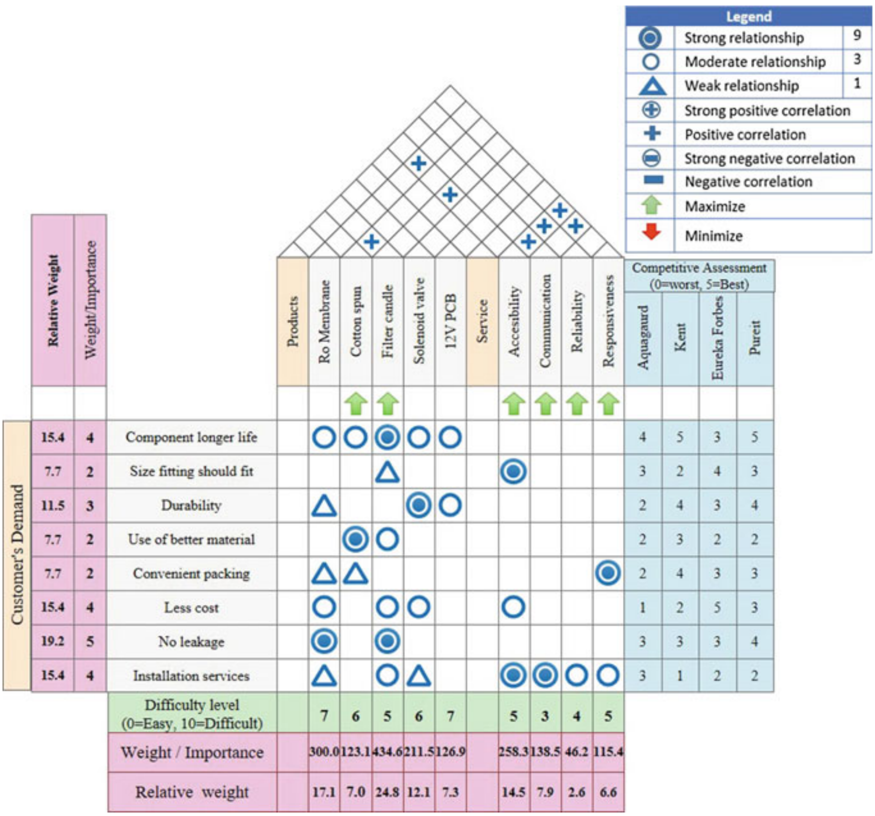


Fig. 16.5 House of quality 1 for the purifier

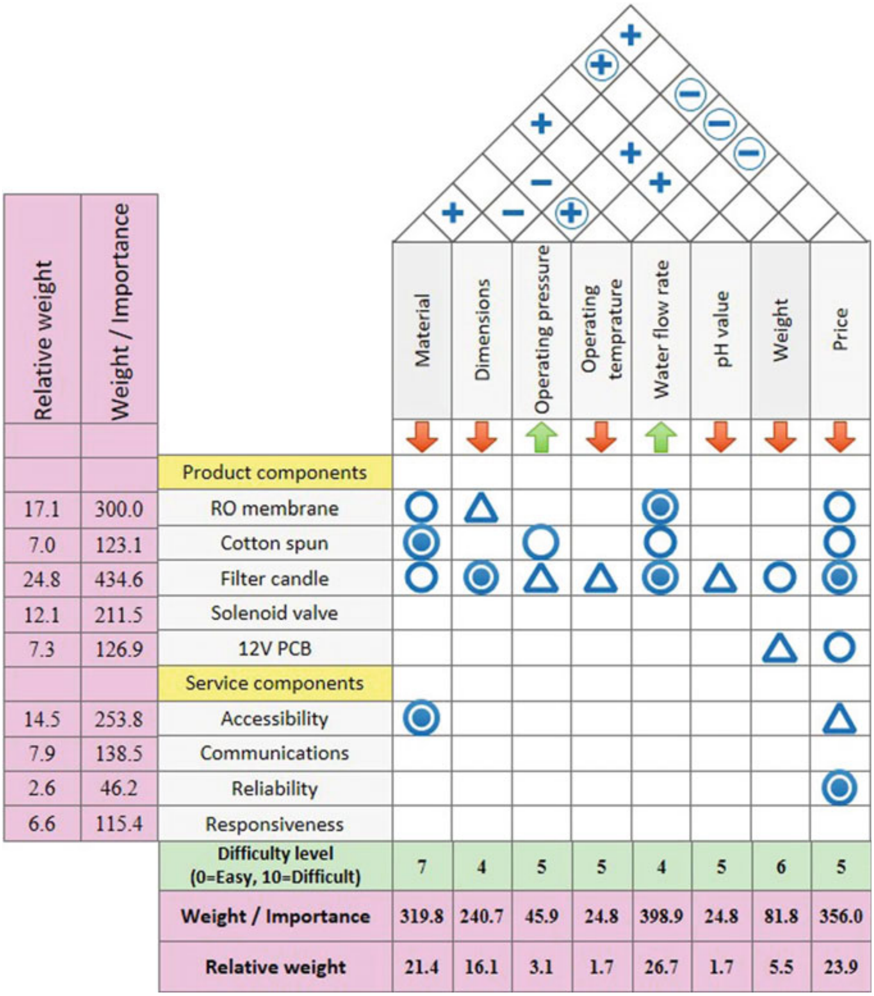


Fig. 16.6 House of quality 2 for the purifier

service-related technical measures, viz. accessibility of filters, communication, reliability, and responsiveness (Fig. 16.5).

The relationship between customer's requirements and functional requirements is developed for water purifier. The relationship is indicated as strong, moderate, and weak along with the associated amount and symbols. One of the customer requirements was leakage of water, which is a strong relationship with technical measures of filter candle on functional requirements.

To identify the interrelationship between each of the technical descriptors, correlation matrix is established, i.e., called the roof of house of quality. To identify the areas to concentrate on next design and to improve needs of customer, the competitive assessment is conducted for purifier product. From the technical descriptors the most important and need to be considered for actions plans: filter candle (434.6), RO membrane (300) and accessibility (253.8) house of quality 2 is the action plan for filter candle as depicted in Fig. 16.6. The technical measures for filter candle product include, viz. material, dimensions of filter candle, operating pressure and temperature, water flow rate, pH value, weight, and price. From the technical descriptors the most important and need to be considered for actions plans: water flow rate (398.9), price (356) and material (319.8).

16.6 Conclusion

The most significant elements in the water supply system were identified in the study. The interrelationships of product–service system of each sub-system of water supply system provided the opportunity for mapping. Mapping was done by using system organization technique. This method of mapping has been found to be effective. The HOQ interprets the voice of customer's into design requirements. Technical descriptors are prioritized based on customer's need and competitor's assessment. Thus, the first three quality characteristics should be prioritized that are the candle element, price, and accessibility of filters. This is a new design management strategy in product–service system in the context of water supply system within a community. The matrix developed for product–service system study will give a new approach to design method in this context. The study will benefit students and academicians involved in design of product–service system and design management.

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Chapter 17
A Fuzzy-Based Approach to Identify Tacit Knowledge in Craft Objects

Sai Prasad Ojha and Pradeep Yammiyavar

Abstract The paper aims to identify and represent tacit knowledge of the craftsman through a fuzzy-based approach. The slow depletion of the crafts culture has been a concern to the researchers. Craft products are being replaced by alternative plastic products. This has depreciated the skills involved in the making of the craft products. An attempt has been made to digitally represent the knowledge embedded in craft objects as well as its roots in the craftsman involved. Knowledge, which is embedded in the craft object, is captured digitally. The paper attempts to answer two basic questions: Is it possible to capture the tacit knowledge of the craftsman in a digital format? If so, how can this knowledge of the craftsman be represented and used in designing more craft products in design? The outcome is in the form of a fuzzy model, which binds the knowledge/skills of the craftsman embedded in his creation. The proposed fuzzy-based model accesses craft products in terms of various design elements like color, shape, pattern, size, and texture value. This fuzzy model developed is a step forward toward categorization of the craft product uniquely in terms of tacit knowledge of craftsman and craft product.

17.1 Introduction

The paper aims to explore and represent tacit knowledge of the craftsman when he/she is involved in the art of making the craft product. There are different approaches in which researchers have tried to represent general knowledge involved during production. Major classification of knowledge is in two categories: explicit and tacit knowledge [1]. The explicit knowledge is the knowledge, which can be coded and can be easily expressible, whereas the tacit knowledge is the knowledge, which is

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very difficult to code as it lies in feelings and emotions and is often tactile. This codification term uses the concept of the codebook [2]. According to this, the codebook is a procedure which is followed by the researcher to present the knowledge in front of others. Thus, explicit knowledge has some standard frameworks and procedure, which can be easily presented in the form of books or written documents, whereas implicit (tacit) knowledge does not have a certain procedure or codebook. It remains as a mental model in the minds of the craftsman, which they display while they perform a certain task. The following questions arise:

1. Is it possible to capture tacit knowledge of the craftsman?

Generally while capturing the activities of the craftsman, a mixture of knowledge is captured. This may be a tacit component as well as the explicit component of the knowledge. This research question helps to see if it is possible to identify, isolate, and extract the tacit component of the knowledge from the above knowledge.

2. If so, how can this knowledge of the craftsman be represented in the design for future use?

The second research question attempts to see if tacit knowledge captured can be represented in the design research cycle of a product. As per the definition by Polanyi [1, 3], the codification of the tacit knowledge is not possible, so how can this knowledge be realized by the users and the designers. The subsequent sections try to solve the above questions. Section 17.2 reports a literature review. Section 17.3 describes the fuzzy-based solution attempted. The fourth section is the inferences and conclusions.

17.2 Literature Review

According to Simon [4], the reason why experts on a given subject can solve a problem more readily than novices is that the experts have in mind a pattern born of experience, which they can overlay on a particular problem and use to quickly detect a solution. This is also seen in various other sectors including the craft sectors. Tacit knowledge is unconscious in nature [2], and it comes automatically when a user performs a task for example when a swimmer swims in the pool; his body is automatically aligned to the rhythm and floats in the water. Likewise when a person learns to ride a bicycle, he falls many times but after certain period learns to get stabilize while riding. Traces of the tacit knowledge can be found when an artist draws a painting or when a craftsman is working on a craft. To identify this kind of knowledge, we need to first see what are the different types identified and associated with the craftsman.

Ancori [5] describes tacit knowledge as the mental models of a human being which are created and manipulated in their minds. According to Ancori [5], there are three analytical challenges which come into effect during the tacit knowledge

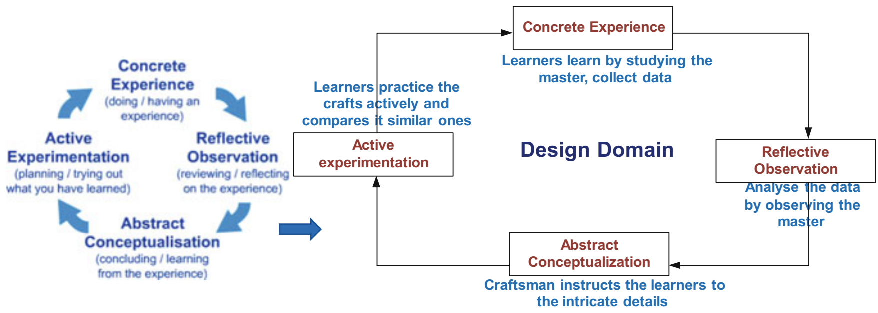


Fig. 17.1 Modified Kolb's model for learning sequence for design domain. *Source* [7]

Fig. 17.2 Nonaka's model of knowledge creation. *Source* [8]

TACIT TO TACIT ***(SOCIALIZATION)*** e.g., Individual and/or Team Discussions	**TACIT TO EXPLICIT** ***(EXTERNALIZATION)*** e.g., Documenting a Team Meeting
EXPLICIT TO TACIT ***(INTERNALIZATION)*** e.g., Learn from a report and Deduce new ideas	**EXPLICIT TO EXPLICIT** **(*COMBINATION*)** e.g., Create a Website from some form of explicit knowledge; Email a Report

propagation. The first is the crude knowledge, which contains a large amount of tacit knowledge in it. The second part is the tacit knowledge, which is present during the communication between individuals. The third part is the knowledge, which remains tacit even in the codes of communication. What is tacit for a person can be explicit for another person. This is seen in learning of new languages as explained by Wittgenstein [6]. Various learning models define the different learning phases. Kolb [7] explained that learning is a process of knowledge creation, which happens by experience. Kolb [7] has proposed a cyclic learning model. Figure 17.1 shows a slightly modified learning model as applied to the field of design.

Nonaka's model [8] also tries to show how the knowledge is converted from tacit to the explicit component. Figure 17.2 shows the Nonaka's model of knowledge creation.

The tacit knowledge appears to be fuzzy in nature and cannot be properly explained by the craftsman expect by using qualitative metaphors [9]. This knowledge of the craftsman makes them unique and distinct from each other. This is sometimes called as "skills possessed by the craftsman" which is difficult to measure.

17.3 Fuzzy-Based Approach

The decisions taken by the craftsman during craft making are intuitive in nature and the thumb rule base which he/she had learnt during his apprenticeship from masters or mentors. In the fuzzy-based approach, the variables adopted are expressed in the form of simple linguistic words which can be easily understood. The topic was first introduced by Zadeh [10] in his 1965 as fuzzy sets. According to him, fuzzy set is defined as follows [10]: 'if *X* be a space of points, with a generic element of *X* as *x*, then

*A fuzzy set **A** in **X** is characterized by a membership function **fA(x)** which associates with each point in **X** a real number in the interval **[0,1]**, with the values of **fA(x)** at **x** representing the "grade of membership" of **x** in **A**.'*

Generally in mathematics, the categorization is discrete in nature, i.e., either a feature belongs to a particular set or does not belong to it. This is not the ideal case in the real-life scenario, in which the data is in the combined state of both discrete and continuous (quantitative and qualitative). However, to have a continuous nature of categorization, we need a continuous function to represent them. For example, we want to measure the weight of a person and specify who is overweight and who is not overweight. Suppose we say that the person who is above 80 kg is considered overweight. The sharp edge membership function describes this and indicates that whether you somebody falls under this category or not. It is very difficult for this type of membership function to describe a real-life scenario (Fig. 17.3).

The continuous membership function helps to tackle this scenario and can describe it. For example, a person of 79 kg can be more toward overweight and less toward a thin person. Figure 17.4 shows a continuous membership function describing the categorization of the weighing problem.

So when there are a large number of real-time variables in a problem, then categorization of the elements becomes easy when we use fuzzy-based approach [11].

In the fuzzy-based approach, the decisions are taken with the formulation of the rules. These rules are "if–then" in nature. The general form of these rules is: "if *x* is *A* then y is *B*," where *x* and *y* are fuzzy numbers in the fuzzy sets *A* and *B,* respectively. These fuzzy sets are defined by membership functions. There can be

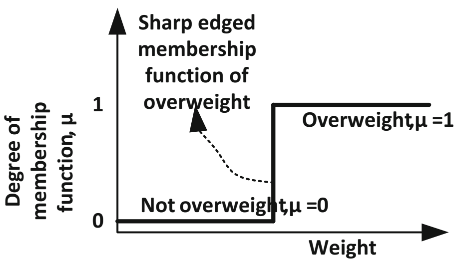


Fig. 17.3 Sharp-edged membership function representing the weight of a person; μ = degree of membership function. *Source* Author generated

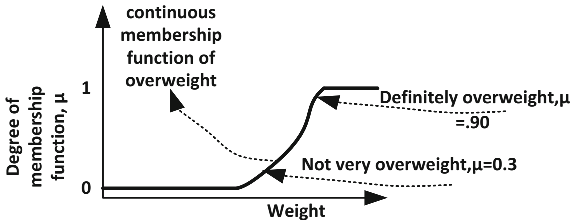
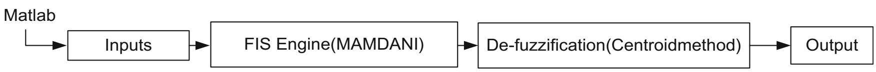


Fig. 17.4 Continuous membership function representing the weight of a person. *Source* Author generated

any number of input and output membership functions for the same input as well, depending on the number of rules in the system. For example, a system could have membership functions that represent slow, medium, and fast as inputs. The relationship between inputs and the output is written in simple sentences. The membership functions from the input variables are then calculated [12] and then defuzzified by a standard method to get the output.



17.3.1 Application of Fuzzy-Based Approach to the Diya (Earthen Lamp) Making Process

The pottery craft is very traditional and it is still practiced in certain communities in India. They are called “khumbhars” in India. Due to the technological advancements, some of these communities are leaving this practice and switching to other industries. The craftsman while making a diya (earthen lamp) inputs his experience to give proper shape and structure to it. Ethnography study [11] helps in understanding the cultural patterns and developing models to explain those patterns. Its application is observed in product design for companies like IDEO, Microsoft, Intel, and BMW. Ethnography study was made on a craftsman working on the production of the diya (Figs. 17.5 and 17.6).

Though the Diya making process looks very simple to the common man, it involves a certain degree of skill of the craftsman. Therefore, to extract these skills the ethnography study of the craftsman was conducted. The mental model of the craftsman during working was mapped. To establish a set of variables for the Diya making model, the craftsman and the process of pottery were studied. During the ethnography study, the craftsman was asked questions like

- What is their age and professional experience?
- How many children are they having and what are they doing right now?
- Why were they staying in this part of the city?

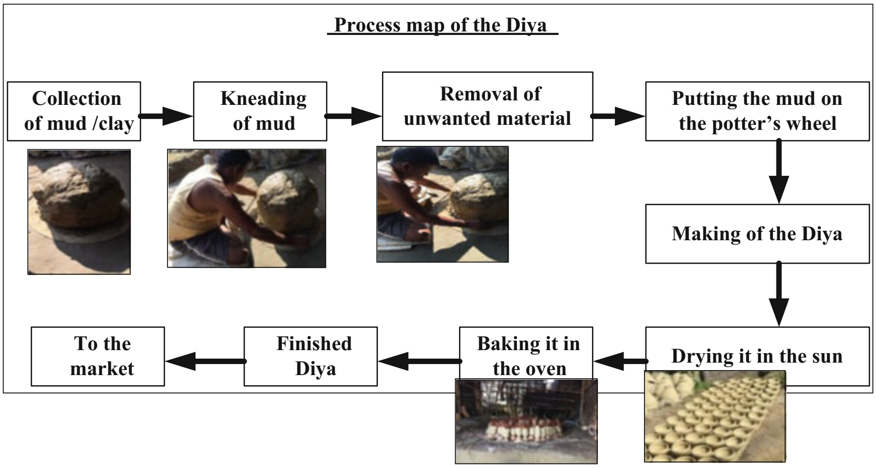


Fig. 17.5 Process map of the diya making. *Source* Author generated

Fig. 17.6 Story board of the diya making process. *Source* Author generated

- What are the other raw materials needed for this craft process?

The results show that they had learnt pottery from their ancestor and were almost practicing it from past 30 years. Some of their children are in the same pottery craft and other siblings have moved into other sectors. Their location was due to the available raw material like good quality of clay nearby. After collating of information from the videos, interaction and field study of the master craftsman geometrical variable (which had a combination of the tacit and explicit component of knowledge) were extracted and analyzed. Table 17.1 shows the protocol analysis of the diya making process with the master craftsman.

The geometrical variables considered after the study of the diya from two different craftsmen. Different features of the diya are taken after analyzing 50 diyas from two different craftsmen. The seven different features identified as follows:

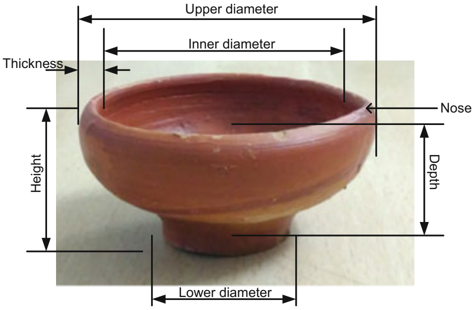
Table 17.1 Protocol analysis of the pottery craft process

Steps	Processes	Photographs/videos	Task/ protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	Implicit knowledge
1	Obtaining the clay		'We have to see the quality and the grain size of the mud/clay'	Chemical composition of the mud should be known	The experience of choosing the mud for a time period has made the craftsman to correctly select the mud quality just by seeing it (color)
2	Kneading the mud/ clay		'We need to knead the mud to soften it'	The mud should be soft enough to get a proper shape	The softness of the mud is known by just touching it with hand
3	Removal of unwanted material		'We need to remove the grass and stones present in the mud'	Removal of unwanted materials is necessary for the smooth product free from cracks	–
4	Making of the Diya		'The Diya has to be round in shape'	Roundness here can be termed into dimensions form	The implicit part here is the extent to which it can be made round depends on the craftsman (variation in the geometrical variations)

(continued)

Table 17.1 (continued)

Steps	Processes	Photographs/videos	Task/ protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	Implicit knowledge
5	Drying the Diyas in the sun		'We need to dry it to make it strong'	The solidness of the Diyas are measured by how dried it is	The craftsman can see the color and feel to judge the dryness of the Diyas
6	Baking the Diyas		'The Diyas are baked'	It gives enough strength and resistant to resist oil during its usage	The color and temperature is set with the experience of baking it for years



Upper diameter, lower diameter, height, nose radius, thickness, depth, and inner diameter

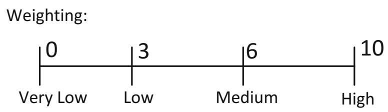


Fig. 17.7 Semantic weighing scale. *Source* Author generated

The geometrical variables were weighted into the semantic weighing scale as illustrated in Fig. 17.7

The upper diameter input feature has a range from 0 to 75. The membership function for the upper diameter feature has three values: low, medium, and high. Here, low corresponds to the lowest possible range of diameter (here 47–54) of diya found from the tacit knowledge of the craftsman. The defuzzification analysis is carried out by converting the triangular fuzzy numbers into exact values [13] (Fig. 17.8).

The membership function for different variables was developed using MATLAB® and is described below. For different inputs like lower diameter, height, nose radius, etc., the membership functions (MFs) were developed. Figures 17.9 and 17.10 show the membership functions. Similarly, the membership functions of all the input parameter have different ranges of low, medium, and high value. These ranges were also fixed after getting the fuzzy inputs from the craftsman and cross-checking with the physical prototypes of the diyas from that craftsman. Out of the various inputs available in the MATLAB, the triangular type of the inputs was considered for the low, medium, and high ranges of the functions. The division of the different inputs helped the researchers to form the rules which can be unique and can help to predict the output easily. The output of the fuzzy inference system (FIS) engine leads to a categorization of the based on the inputs. The membership function of the output of the FIS is shown in Fig. 17.11. After the development of the membership functions, the fuzzy rules were framed for the Diya model.

Initial phase of the FIS system consisted of few rule as shown in Fig. 17.12. Gradually, the rules of the fuzzy system were increased. This was from the tacit knowledge gained from the craftsman of the particular diya. Some of the rules which are formed are as follows:

If (LowerDia is high) and (UpperDia is Low) and (Height is Low) and (NoseRadius is low) and (Thickness is low) and (Depth is low) and (InnerDia is low), then (DiyaClassifier is DiyaWBSmaller)

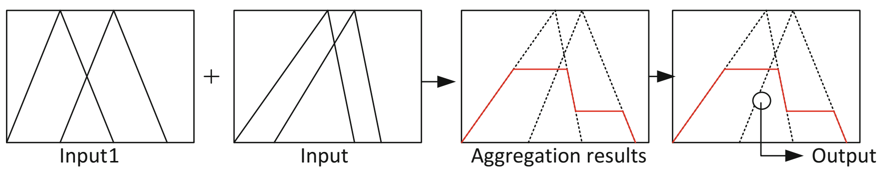


Fig. 17.8 Defuzzification results of two input functions. *Source* Author generated

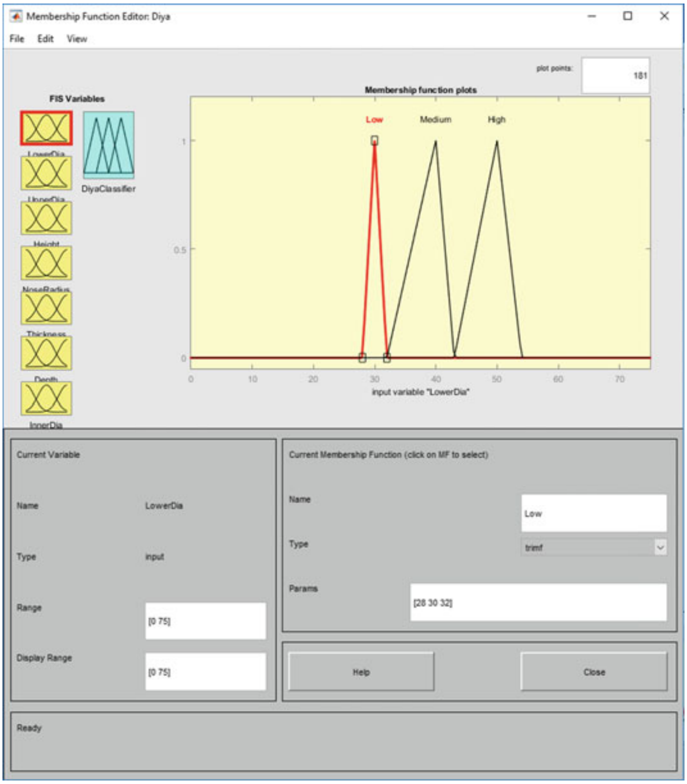


Fig. 17.9 MF for upper diameter input parameter

If (LowerDia is high) and (UpperDia is High) and (Height is Low) and (NoseRadius is low) and (Thickness is medium) and (Depth is low) and (InnerDia is high), then (DiyaClassifier is DiyaWBLarger)

…

…

Figure 17.13 shows the rules involved in the shape FIS engine.

Similarly, the FIS system was developed for the other features pointed out in the previous section for diya and then combined together and was implemented into the machine engine.

17.4 Inferences and Conclusions

The results show that for the various geometrical inputs, which are taken as a feedback from the master craftsman cross verifying with the real product; used in the FIS engine could classify two different product of same class like for diya one

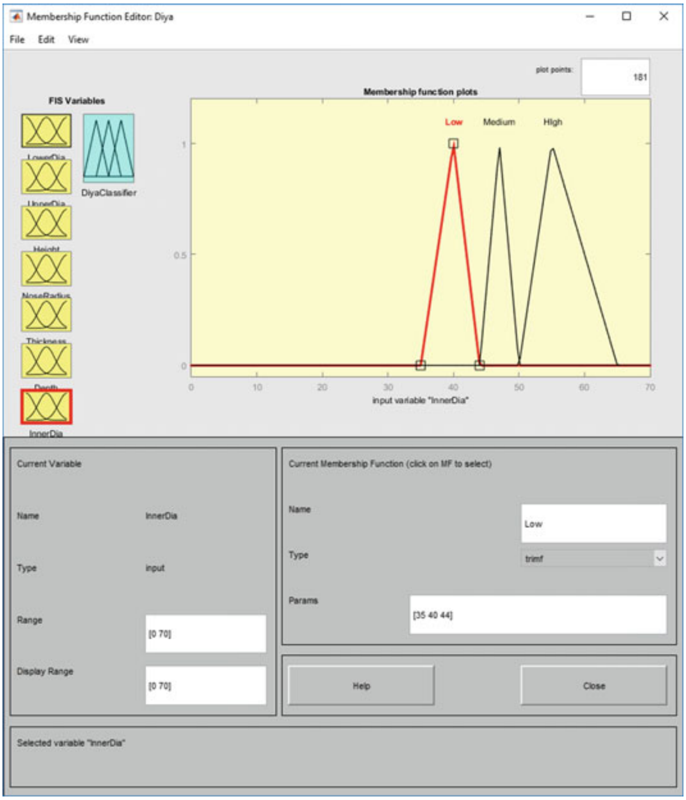


Fig. 17.10 MF for inner thickness input parameter

category was from West Bengal, India and the other was from Bihar, India. The tacit knowledge of the craftsman which was embedded in the product was useful in the categorization of the product. Though it was difficult to fully classify all the tacit knowledge of the craftsman involved in the work, an attempt was made to distinguish some of them.

Some of the tacit knowledge of the craftsman was represented in the geometrical variables as shown in the above study. This is an attempt to answer the second research question raised during the study. Though it is complex task to convert all the tacit knowledge possessed by the craftsman into explicit knowledge.

The FIS system just gives a brief idea to classify objects in the similar class; the system can be useful in studying the objects whose distinction cannot be made by the minute difference which are created in them due to the visual features. The FIS system can be used in correlation with the simulation tool of different applications which can help in distinguish between the craft objects. Though the system is not robust in its current version, with more number of similar objects details can help in

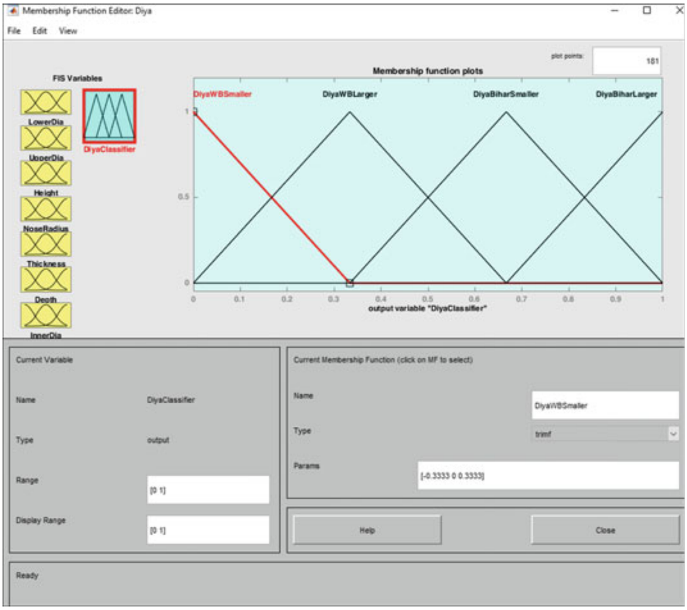


Fig. 17.11 Output MF of the diya.fis system

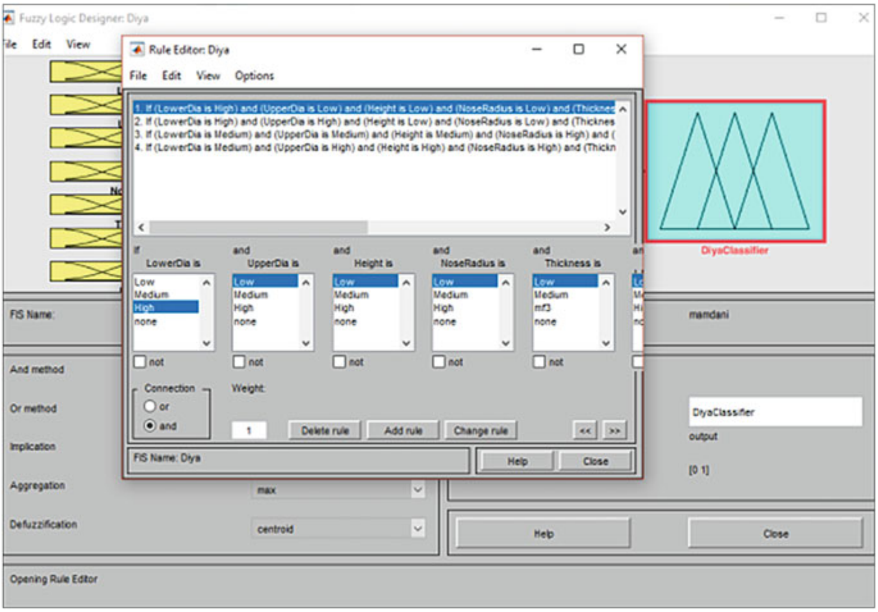


Fig. 17.12 Rules to classify the diya based on the shape of the diya

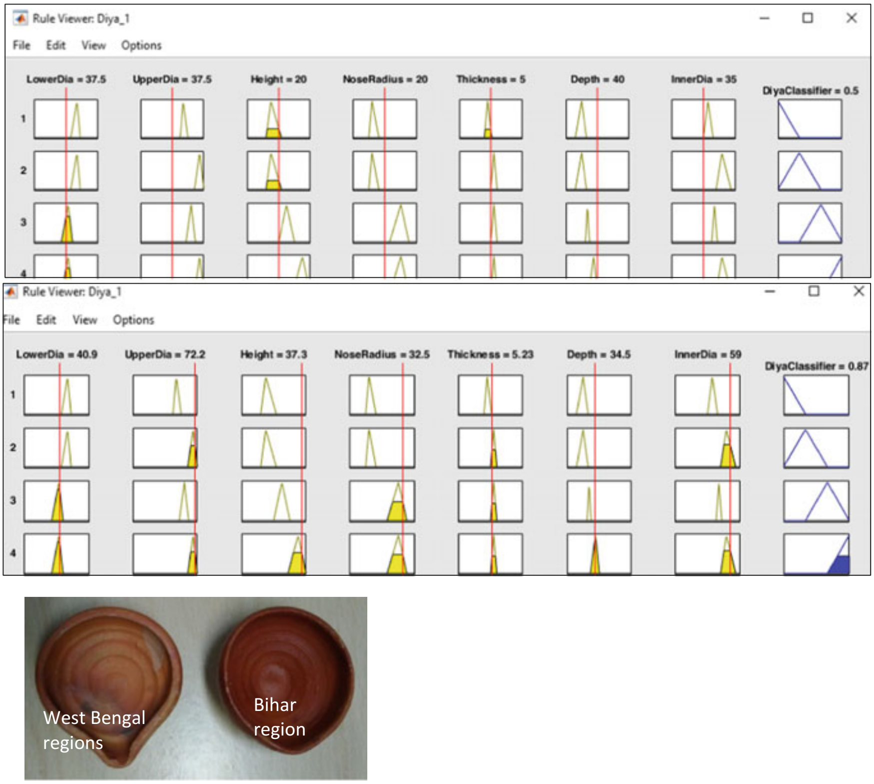


Fig. 17.13 Rule implementation of the diya FIS system

making it sound. Attempts are made to increase the number of similar objects in the future system.

This is an initial attempt toward the representation of the tacit part of the knowledge through fuzzy logic approach. Only the case of pottery is undertaken in the above paper, which can be carried out for more number of cases.

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Chapter 18
Ethical Ideologies in Purchasing Attitudes Towards Counterfeit Fashion Brands

Indranil Saha and Deepak John Mathew

Abstract Fashion brands offer iconic associations with the consumers about their personalities and approaches, which are beyond their basic need of product features. Counterfeit fashion brands are similar or confusingly similar copies of authentic fashion brands and these are typically available at a fraction of the original product price with lower quality. The purpose of this study was to measure Indian consumers' ethical and other values based on various factors affecting the consumer-purchasing attitude of counterfeit fashion brands. The study determines important predictors of attitude towards counterfeits as fashion and brand consciousness and social impact. This study also supports the fact that attitude towards counterfeit fashion brands leads to ethical judgement and ideologies and is negatively influenced by consumer's ethical consciousness. The findings of this study may benefit fashion brand marketers, producers and practitioners in their marketing communication to design their branding strategies in the Indian context.

18.1 Introduction

Brands symbolize the new-fangled life of fashion consumers. As brands are the representation of quality and reliability, they play a major role in changing the lifestyle of consumers drastically [1]. Fashion brands offer more iconic associations to the consumers about their personalities and approaches, which are beyond their basic need of product features [2]. With branded fashion market value growing at such a prodigious rate, many fashion-related brands have become targets for counterfeit manufacturers [3]. Counterfeit products are similar or confusingly similar copies of authentic brands and products. Typically, a counterfeit product is available at a fraction of the original product price with lower quality; however,

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these products possess high brand value and are often associated with bargains acquired on busy city or suburban street shops [4]. Faster manufacturing of counterfeit products due to rapid advancements in technology [5] and high demand for counterfeits due to the quest for status, stylish and trendy products [6] are important reasons behind counterfeiting of branded products. Whereas the supply side of manufacturing duplicate items has been considered to be researched largely, inspections focusing on the demand side are still sporadic [7]. Factors affecting consumers' purchasing attitude also influence the purchase of counterfeit fashion-related products. Previous research has found and validated those factors to be fashion and brand consciousness, social impact and ethical consciousness [8].

On the other hand, past literature suggests that purchase attitude of counterfeit products is strongly interrelated with consumer's ethical ideologies [9]. Consumer ethics can be influenced by factors materialistic values and social groups and may involve issues like purchase of counterfeit products [10]. An understanding of the mindsets that consumers possess as they rationalize unethical consumption decisions is critically important to researchers and policy makers both [11]. However, past researches mainly focus on countries and regions except India. India as a country has different income, purchasing power, cultural and brand consciousness pattern [8]. This study becomes more relevant as very few studies have been conducted in the local context. This study addresses the relationship between the purchase attitude of counterfeit fashion brands and consumers' ethical ideologies that guide buying behaviour of counterfeit fashion brands. The findings of this study may benefit fashion brand marketers, producers and practitioners in their marketing communication to design their branding strategies in Indian context. Hence, the research question of this study is, "is there a significant relationship between the purchase attitude of counterfeit fashion brands and consumers' ethical ideologies that guide buying behaviour?"

18.2 Literature Review

In order to identify the relationship between consumer's ethical ideologies and purchase attitude towards counterfeit fashion brands, the core concepts of counterfeits, fashion and brand consciousness, pre-researched factors that influence consumer's attitude towards the counterfeit purchase are reviewed.

18.2.1 Counterfeits

Counterfeits are procreations of a renowned–trademarked brand [12], which are almost similar or identical to original products. Although piracy is primarily associated with film, music recordings and software [13], the terms counterfeiting and piracy have been used interchangeably [14] as they are both cheaper replica of original products [15]. These may reduce the iconic value of original brands and weaken brand equity [16]. When a consumer cannot distinguish between a copy and an original product and unknowingly makes a purchase of a counterfeit article is referred to as deceptive counterfeiting. If consumer intentionally purchases, a counterfeit product is categorized as non-deceptive counterfeiting [16].

18.2.2 Theories of Attitudes

Attitude is defined as an assessment of the consequences of acting or merely as an evaluation process [17]. Consumers have a preference towards copies of a renowned brand name, as that would offer some association of prestige to the consumer. Consumers who purchase counterfeit brands tend to get attracted by the visual attributes and features rather than quality and they end up paying for them [12].

Attitudes also propose significant social functions. "Social-adjustive attitudes" serve people in retaining relationships, and they are encouraged to consume a product to have a social appreciation; "value-expressive attitude" serves people to communicate their core values, attitudes, and beliefst, and they are encouraged to consume the product to form a self-expression [18]. Previous research has indicated that a social-adjustive function and/or a value-expressive function may be served by consumers' attitudes towards authentic brands [19].

18.2.3 Fashion and Brand Consciousness

Fashion consciousness refers to individual's degree of association with the trends of clothing. Various researches have reported diverse findings on the impact of fashion and brand consciousness on counterfeit purchases. The purchase intention of counterfeit brands is directly related to the prestige and positioning of the original brand, as the need of flourishing can be achieved [20]. Brand-conscious consumers have a negative attitude towards counterfeit products [16]; however, if the quality and aesthetic features are replicated flawlessly, the brand-conscious consumers may also buy counterfeits [3]. Brand image is also found to be a major influencer on attitude towards counterfeit [21]. The hypotheses are proposed as follows:

H_1 Fashion and brand consciousness have a negative influence on attitude towards counterfeit fashion brands.

18.2.4 Social Impact

Social impact is recognized as the influence that one exerts on another person's behaviour [22]. Social class rather than merely income significantly influence consumer-purchasing attitude [23]. Consumers purchase a product keeping in mind what others perceive of them and they are more mindful about their self-image. Consumers purchase branded products to project status, wealth and class [24]. If the brand name is important to the consumers and it is too expensive to afford, they turn to counterfeits. Peer pressure leads a consumer to purchase original or counterfeit products and social impact has a strong influence on attitude towards counterfeit products [3]. Hence, the following hypothesis is proposed:

H_2 Social impact has a positive influence on attitude towards counterfeit of fashion brands.

18.2.5 Ethical Consciousness

Ethical consciousness is defined as the value that one possesses and believes in [25] by assessing people's opinion about the moral rightness or wrongness of a conduct [26]. Consumer ethics as the moral rules, values and standards guiding the behavior of a person [27]. Former research has found that purchase attitude towards fashion products has been affected by ethical beliefs about counterfeits, and thus, consumer behaviour is influenced by ethical judgements. Purchasing duplicate items infringes common norms in the marketplace [28]. Consumers valued ethical issues more important while buying counterfeit fashion products than while buying other consumer products [29]. Hence, a strong ethical consciousness can be related to consumer attitude towards counterfeit fashion brands. The following hypothesis is derived:

H_3 Ethical consciousness has a negative influence on attitude towards counterfeit of fashion brands.

18.2.6 Ethical Ideologies

Ethical ideologies are guidelines for behaviours that are morally suitable. There are two dimensions of ethical ideologies in order to measure individual differences, idealism and relativism [30]. Idealistic people consider that harming others has negative consequences, whereas relativistic people believe that universal moral principles should be moderated by considering their consequences [31]. In the context of counterfeit purchase, more idealistic consumers might be expected to have a negative attitude towards counterfeit purchase, whereas more relativistic consumers might be able to foresee consequences when counterfeit purchasing might result positively and become acceptable. The following hypotheses are derived:

H_{4a} Attitude towards counterfeit of fashion brands has a negative influence on idealism as a dimension of ethical ideologies.

H_{4b} Attitude towards counterfeit of fashion brands has a positive influence on relativism as a dimension of ethical ideologies.

18.3 Methodology

The quantitative approach of collecting data, which refers to structured empirical research in any areas through statistical and mathematical techniques to develop related mathematical models and hypotheses, was opted in the study.

18.3.1 Sample

The research sampling was nominated from the consumers studying and working at various national level institutes through convenience sampling method. As India has more than 65% population below the age of 35 [32], they have a good potential for consuming fashion brands. Institutes, where students and employees come from different regions of the country, were targeted. Past research has identified that university students as a consumer segment that knowingly make counterfeit purchase decision [12]. 589 respondents participated in the survey during the dates of March 30 and April 23, 2018. However, 565 responses were found to be eligible for analysis. A pilot study with 30 respondents was done before the actual data collection, in order to ensure the clarity of instructions and wording of the questions.

18.3.2 Data Collection and Analysis Tool

For gaining required and appropriate information, data for this study was collected through an online survey questionnaire. Table 18.5 (in Appendix) lists the variables and items of research questionnaire. Moreover, five-point Likert scales were used as they are less biased by different response styles [33]. All respondents and their answers were treated confidentially and it was ensured that the used measures were found to be valid and reliable in previous research. IBM SPSS Statistics 20.0 was used in analyzing the collected data.

18.3.3 Delimitation of the Study

This study is limited to only four independent variables on attitude towards counterfeit purchase. Moreover, this research is bound with the limitations of convenience sampling. This study is also limited to counterfeiting of fashion brands only.

18.4 Data Collection and Analysis

18.4.1 Demographics

38.9% of the respondents are female, and 58.4% are male. Majority is 20–24 years old with 41.6%, followed by 25–29 years old with 38.9, 29.2% of the respondents were deceptive counterfeit consumers, whereas 28.3% were non-deceptive counterfeit fashion consumers.

18.4.2 Reliability of the Measurement Model

The measurement model of this study includes variables, namely attitude towards counterfeit fashion, fashion and brand consciousness, social impact, ethical consciousness and ethical decision-making. First, reliability of the variables was measured for the structural model. The results of item reliability were found in acceptable levels as shown below (Table 18.1). In our model, Cronbach's Alpha ranges from 0.683 to 0.931, which exceed the recommended limit of 0.60 value.

18.4.3 Hypothesis Validation

In order to test the hypotheses (Hypotheses 1–3), multiple regressions were used to analyze the influences of the independent variables on attitudes towards counterfeits of fashion brands as shown in Table 18.2. A multiple regression was run to predict

Table 18.1 Reliability scores of the constructs

Variables	No. of items	Cronbach's Alpha
Fashion and brand consciousness	5	.831
Social impact	12	.888
Ethical consciousness	4	.895
Ethical ideologies	9	.683

Table 18.2 Determinants of attitude towards counterfeits of fashion brands

Independent variables	Standardized coefficients beta	*t*-statistics	*p*-value
Fashion and brand consciousness	.163	4.283	.000
Social impact	.197	5.255	.000
Ethical consciousness	.341	10.201	.000

Dependent Variable Attitude towards counterfeit fashion brands
R^2 = .425; F = 103.637 (significant at $p < 0.05$)

attitude towards counterfeit fashion brands from fashion and brand consciousness, social impact and ethical consciousness. The adjusted R^2 of our model is .421 with the R^2 = .425. This means that the linear regression explains 42% of the variance in the data. The Durbin–Watson d = 1.967, which is between the two critical values of $1.5 < d < 2.5$. Hence, this indicates a good level of prediction. The independent variables statistically significantly predicted attitude towards counterfeit fashion brands, F (4560) = 103.637, $p < .05$ and R^2 = .421. All four variables added statistically significant to the prediction, $p < .05$.

Based on the above-mentioned results, all four variables namely fashion and brand consciousness, social impact and ethical consciousness are found to be significant determinants of attitudes towards counterfeits of fashion brands.

Finally, in order to test the hypotheses 4a and 4b, multiple regressions were used to analyze the influence of attitudes towards counterfeits of fashion brands towards idealism and relativism as dimensions of ethical ideologies as shown in Tables 18.3 and 18.4. A multiple regression was run to predict idealism as a dimension of ethical decision-making from attitude towards counterfeit fashion brands. The adjusted R^2 of our model is .170 with the R^2 = .810. This means that the linear regression explains 17% of the variance in the data. The Durbin–Watson d = 2.052, which is between the two critical values of $1.5 < d < 2.5$. Hence, this indicates a good level of prediction. The independent variable statistically significantly predicted idealism, F (1563) = 10.526, $p < .05$ and R^2 = .170. The variable is statistically significant to the prediction, $p < .05$.

Based on the above-mentioned results, attitude towards counterfeit fashion brands is found to be significant determinant of idealism as one of the dimensions of ethical ideologies.

Table 18.3 Influence of attitudes towards counterfeits of fashion brands towards idealism

Independent variable	Standardized coefficients beta	*t*-statistics	*p*-value
Attitude towards counterfeit fashion purchase	.135	3.244	.001

Dependent Variable Idealism as dimensions of ethical ideologies
R^2 = .170; F = 10.526 (significant at $p < 0.05$)

Table 18.4 Influence of attitudes towards counterfeits of fashion brands towards relativism

Independent variables	Standardized coefficients beta	*t*-statistics	*p*-value
Attitude towards counterfeit fashion purchase	.236	5.773	.000

Dependent Variable Relativism as dimensions of ethical ideologies
R^2 = .540; F = 33.324 (significant at $p < 0.05$)

A multiple regression was run to predict relativism as a dimension of ethical decision-making from attitude towards counterfeit fashion brands. The adjusted R^2 of our model is .540 with the $R^2 = .560$. This means that the linear regression explains 54% of the variance in the data. The Durbin–Watson $d = 2.089$, which is between the two critical values of $1.5 < d < 2.5$. Hence, this indicates a good level of prediction. The independent variables statistically significantly predicted relativism, F (1563) = 33.324, $p < .05$ and $R^2 = .540$. The variable is statistically significant to the prediction, $p < .05$.

Based on the above-mentioned results, attitude towards counterfeit fashion brands is found to be significant determinant of relativism as dimensions of ethical ideologies. To summarize, Hypothesis 1–4 were accepted.

18.5 Findings and Conclusion

This research examined the key influencers of attitude towards counterfeits, which lead to ethical ideologies and judgements. Research findings reveal that fashion and brand consciousness and social impact have a positive impact on attitude towards counterfeit of luxury brands. The current study establishes the fact that fashion and brand consciousness has a positive impact on counterfeit purchase attitude, which is not consistent with the finding of a study on Singaporean consumers [3]. Researching the topic in Indian context clearly shows different outcome to attitude towards counterfeit purchase. In the Indian context, consumers are aware of fashion brands, but they might not have adequate awareness about the significance of their originality. This study resonance the findings of the previous studies [34] that consumers are influenced by social impact, which is an influencing factor towards attitude towards counterfeits. Indian consumers choose to be recognized by their peer groups to live up to their expectations when it comes to branded clothing consumption. The above findings suggest fashion brands producers should acquire additional understandings into manoeuvering their anti-counterfeiting campaigns. It is important for fashion brands to target consumers accurately, which are influenced by their colleagues. Ethical consciousness has a negative influence on attitude towards purchase for counterfeit of fashion brands. The finding also is consistent with the previous literature [35]. Indian consumers, who are cognizant about ethical values, recognize counterfeiting as an unethical practice. The result is vital specifically for the marketing communication of the fashion brands and NGOs. The fashion brands should give effort to communicate with the consumers on the negative impressions of counterfeiting and the potential threats it will cause, as counterfeits are without quality and guarantees. After statistically analyzing the influencing variables, the study answers the research question by establishing that there is a significant relationship between the purchase attitude of counterfeit fashion brands and consumers' ethical ideologies that guide buying behaviour. Purchasing attitudes towards counterfeit fashion brands reflect on consumers' ethical decision-making, which may give the fashion brands to have a socially responsible approach while manufacturing and communicating their products and novelty features. Although ethical ideologies do not depend on someone's socioeconomic position in society [36], this study suggests social impact has a significant effect on perceptions of consumption ethics among Indian consumers. Additionally, consumers, who enjoy shopping counterfeit fashion products, consider that not following preset moral ideologies will not necessarily have any negative social and ethical consequences. In Indian scenario, consumers' ethical ideologies and purchasing attitudes towards counterfeit fashion products may be affected by unethical activities from the business side, as ethical consciousness has a negative influence on attitude towards counterfeit of fashion brands.

Counterfeiting is a growing concern in India as the counterfeit brands are slowing entering into lesser-known e-commerce portals as well. One of the key issues is, in Indian consumers' perception, counterfeit which is not an unethical activity, and hence, they are mostly unresponsive towards the issue [8]. Sufficient planning to control all the stakeholders at both demand and supply side can solve the issue. The research examines only limited number of non-price determinants on attitude towards counterfeit purchase. Future researches can include more variables like materialism, perceived risks, economic and hedonic benefits, complex sociological elements that lead to ethical decision-making. Moreover, non-probability sampling of this study is not representing the whole population truly. Counterfeit of fashion brands is only one extent of counterfeiting. Other areas such as specific counterfeit brand, first copies, custom-made copies, mass-market brands who often derive their designs from high-fashion designer brands (e.g. Zara, Gap and H&M), which may also affect the attitude of consumers to purchase counterfeits can also be researched further.

Appendix

See Table 18.5.

Table 18.5 Variables and items of research questionnaire

Variables	Items
Fashion and brand consciousness (FBC)	**FBC1.** An important part of my life is to dress smartly. **FBC2**. While choosing between fashion and comfort, I usually dress for fashion as compared to comfort. **FBC3**. It is important to me that my clothes represent the latest trends. **FBC4**. I usually have more than one outfit of the latest fashion style. **FBC5**. It is important for people to dress in the latest styles
Social impact (SI)	**SI1**. I rarely purchase the latest fashion styles until I am sure my friends approve of them **SI2**. It is important that others like the products and brands I buy. **SI3**. When buying products, I generally purchase those brands that I think others will approve of. **SI4**. If other people can see me using a product, I often purchase the brand they expect me to buy. **SI5**. I like to know what brands and products make good impressions on others. **SI6**. I achieve a sense of belonging by purchasing the same products and brands that others purchase. **SI7**. If I want to be like someone, I often try to buy the same brands that person buys. **SI8**. I often identify with other people by purchasing the same products and brands they purchase. **SI9**. To make sure I buy the right product or brand, I often observe what others are buying and using. **SI10**. If I have little experience with a product, I often ask my friends about the product. **SI11**. I often consult other people to help choose the best alternative available from a product class. **SI12**. I frequently gather information from friends or family about a product before I buy
Ethical consciousness (EC)	**EC1**. I would feel guilty if I bought counterfeits. **EC2**. Counterfeit goes against my principles. **EC3**. It would be morally wrong for me to buy counterfeit. **EC4**. Counterfeiting is unethical behavior
Ethical ideologies (EI)	**EDM1**. I download music from the internet instead of buying it.[a] **EDM2**. I buy counterfeit goods instead of buying the original manufacturers' brands.[a] **EDM3**. I buy products labeled as "environmentally friendly" even if they do not work as well as competing products. **EDM4**. I purchase something made of recycled materials even though it is more expensive. **EDM5**. I buy only from companies that have a strong record of protecting the environment. **EDM6**. I believe in recycling materials such as cans, bottles, newspapers, etc. **EDM7**. I return to the store and paying for an item that the cashier mistakenly did not charge me for correcting a bill that has been miscalculated in my favor. **EDM8**. I give a larger than expected tip to a waiter.[a] **EDM9**. I do not purchase products from companies that I believe do not treat their employees fairly

[a]reversed during analysis

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Chapter 19
Making the Best of Obsolescence—A Study on the Changing Landscape of Product Life-Cycle

Nithya Venkataraman and N. Elangovan

Abstract Fashion, it is said, thrives on change. Its interception with the consumer is mapped by a well-defined lifecycle, going through stages of Introduction, Rise, Peak, Decline and Obsolescence. Unlike many other products that follow the S-shaped PLC curve, fashion products are marked by a definite period of obsolescence, planned or otherwise. This period of obsolescence marks the uniqueness of this business, promoting the existence of seasonality and trends in the dynamic fashion environment. Traditionally, the period of obsolescence had been a source of worry for marketers and supply-chain personnel. Pertinently, obsolete merchandise that is not liquidated and consumed contributes to landfills amassing massive earth-space, dangerously compromising on the fragile ecosystem of our planet. This study employs quantitative methods to infer the relationship between the "innovativeness" of a consumer and the perceived value of obsolete or End-of-lifecycle (EOLC) products in fashion, and the consequent impact on purchase intention. It also maps the consumer perceived value when presented with a "deconstructed" garment, and seeks to explore the relationship of an innovative fashion consumer and his response in terms of value perception and purchase intention for deconstructed garments.

19.1 Introduction

> "**Innovation distinguishes between a leader and a follower**"—Steve Jobs, visionary product designer and innovator

In a world that is going through a constant flux of consumption patterns, these are wise words that define what makes any consumable product a long game-player in the marketplace. The natural course of change in consumption makes the product

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go through a distinct lifecycle with respect to its acceptance—starting with an introduction phase, peaking in popularity after a steady rise and gradually declining till it reaches a level of obsolescence, wherein it is no longer preferred by the consumer. The reasons for its rejection by the consumer can be multitude—introduction of a more viable product which displaces its position, a change in socioeconomic situations, seasonal variations, or just a feeling of boredom by the consumer.

Fashion retail is on the throes of innovation today. The advent of online space has created opportunities for Omnichannel retailing, making it possible for brands to reach out to a larger consumer base, with wider product lines, added convenience and maybe even lower price points. For the fashion business, obsoleting is a necessary evil. To quote Neil Maycroft, "all must be made obsolete according to capital's logic, such that all needs should be satisfied via the consumption of commodities, new needs are created to be satisfied in the same way and all needs and their commodified satisfactions should be continually renewed in order to secure continual and expanding consumption" [1]. It is only with the obsolescence of product lines that newer fashion replaces the old and outgoing, making the bell-shaped movement of the fashion lifecycle possible. However, this is indeed a double-edged sword. Such merchandise at the end of their lifecycle stage needs to be dealt with in a faster and more efficient manner. Traditional practices for liquidation of such merchandise are practiced across all channels of distribution. Retailers tend to Markdown prices, necessitating preplanning during pricing for the merchandise to contribute the required margins. They may also sell these consignments to discount stores or factory outlets, which may again require recalculation of the margins. Retailers also tend to "bundle" them with fast-moving categories, but this again leaves them with negligible focus on the margins contributed. Short lifecycle fashion products are expensive to hold or carry. They take up retail shelf space, blocking opportunity for more relevant merchandise to make margins, and occupy premium storage space at warehouses. Sales forecasts and likewise tools, undoubtedly, allow today's fashion brands to avoid the costs of managing obsolescence. However, these methods still leave the retailer with merchandise that is obsolete.

Thankfully, fashion products have the capacity to undergo modification or redesign, envisaged in today's fashion runways as "deconstructed" garments. Changes in the aesthetic appearance of such products may actually be able to position them as new SKUs, or stock-keeping-units; making them no longer an "obsolete" product. However, it is possible that the consumer holds a varied value perception to such a product. It is a matter of no debate that this perceived value will be an influencing factor on the consumers' intention to purchase. The relationship between these factors drives important strategic decisions for attempting deconstruction in EOLC fashion, and probably making them sustainable options that can extend their lifespan.

19.2 Theoretical Framework

19.2.1 The Product Lifecycle (PLC)

The foundation to the product lifecycle concept was laid by Everett. M. Rogers in his seminal work on the diffusion of innovations [2]. Rogers opines that "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" and postulates that the movement of this innovation in a "social system" follows a distinct curve, thereby breaking the category of adopters into "Early" and "Late" adopters.

The adoption curve proposed by Rogers was modified to capture the cyclic nature specific to fashion merchandise. Movement and consumption of fashion merchandise are hence diagrammatically represented through a fashion lifecycle, which indicates the stages of adoption that every "innovative" product goes through. The theory adapts the same cycle for any new or innovative product, making it run through a clear life cycle before it hits obsolescence. Products go through a shift in their value to the market, eventually losing or at-least decreasing its value by the time it reaches the obsolescence stage. For the high turnaround and extremely market-driven fashion business, the perceived value of its merchandise tends to shift as it moves along the traditional product lifecycle (PLC), inherently due to the nature of the product to follow timeline-based trends. This leads to detailed strategies for liquidation of such merchandise among the marketing, supply-chain, and logistic domains.

19.2.2 Challenging the Product Lifecycle

With the shift in buying patterns among today's digital natives, the concept of obsolescence needs to be re-interpreted. The PLC concept has also been challenged time and again due to the many factors that this rather simple theory failed to address. Nariman and Yuspeh reject the lifecycle concept under the arguments of it being unable to capture the possibility of revitalizing products at the decline stage by smart promotion, reengineering, or repositioning [3]. Paul Steffens revisits the PLC and converts it into a four-stage model of innovation, imitation, repeat, and substitute [4]. His study elaborates on the PLC sales pattern, which does usefully approximate an "S" shape, but offers no guidance as to the timing of the transition between stages. In such a scenario, the relationship between the lifecycle and the perceived value needs to be revisited. Many studies have been devoted toward developing economic and stochastic models to address the issue of EOLC products, unsold merchandise and to the methods of liquidation employed for such merchandise. However, the consumer perspective toward a revised value proposition, specifically in the wake of newer models of consumer behavior, still needs to be explored.

19.3 Development of Constructs

End of lifecycle merchandise has been the focus of study across multiple domains. Usanmaz [5] identifies that the final phase of a product's life, which is as important as its introduction to market, must be managed to avoid loss of profits and damaged relationships. His exploratory study focuses on business practices in the management of products in the decline phase and the eventual decision of product abandonment. The units of analysis were senior executives from Fortune 500 companies, focusing mainly on food, networking equipment, medical devices, consumer electronics, and retail industries. Daniel & Devavrat postulate that consumers' expectation of a forthcoming product lowers the price that they are willing to pay for the current product because of its loss in value due to obsolescence [6]. They identify that the new product is characterized by consumers' increased willingness to pay and by its competitive interaction with the old product. This interaction is presented as an economic model that plays the interaction of policy measures available to the firm, including limiting initial sales in order to lower cannibalization of the new product, buying back the earlier version of the product in order to generate greater demand for the new product, and announcements of future product introduction. Steffens argues that the PLC concept ignores consumers, apart from areas concerning sales growth [4]. He rues on the lacuna in PLC which essentially bases strategy guidelines on the current and expected sales growth, together with the expected competitive intensity. His paper consolidates literature to develop an over-arching conceptual PLC model and managerial tool for consumer durables. The approach defines the new PLC phases based on some key consumer trends during product- market evolution, resulting in a four-phased PLC model: Innovation → Imitation → Repeat → Substitute. Birou, Fawcett, and Magnan propose an integrative strategic framework utilizing the PLC as a "common strategic denominator," integrating functional strategies such as production, logistics, and purchasing with the PLC to arrive at a holistic business strategy [7].

While studies on the PLC and obsolescence have focused on the movement of product, it is pertinent to note that this movement results in varied value perception of the said product. Perceived value is a core concept in product development that has gone through endless iterations in literature. Innumerable studies define it as "the difference between benefits perceived by the client and sacrifices that he must do to get that product. Zeithaml postulates that perceived value is based on customer's experience and is seen as a compromise between benefits and sacrifices, as evidenced by Flint et al. and Gronroos [8, 9] or between quality and sacrifices, as studied by Monroe Ronald and Gronroos [9, 10] which can be divided into financial and psychological sacrifices. Varki and Colgate identify price as a representative of one of the most important components that drive value perceptions [11], and that it plays a critical role in influencing customer satisfaction levels as evidenced from studies by Bolton and Lemon [12] and Parasuraman and Grewal [13]. Sheth identified five dimensions of the concept of value—Functional, Emotional, Social, and Conditional (relates to situational factors such as the disease or specific social situations). [14] It is also possible that customers across different cultural backgrounds and from varied social environments react differently with respect to value. Gloria Meng suggests that "culture factors do have significant effects on price perception" [15].

The inherent perception of value among consumers of fashion is thought to decline as and when the product dips in its lifecycle curve. The change in value perception is expected to influence the consumer's decision to purchase the product, and consequently, the impact on its business performance. Purchase intention has been identified as a clear indicator of possible purchase by a consumer. Dodd's, et al. define it as the possibility of a consumer to buy a product, and that "the higher the purchase intention is, the higher a consumer's willingness is to buy a product." [16] Chang and Wen Chen discuss whether online environment cues (Web site quality and Web site brand) affect customer purchase intention toward an online retailer [17]. Grewal, Monroe, and Krishnan postulate in their seminal paper on reference pricing that the purchase and search intentions are influenced by the perceived transaction value of the products [18].

With a pathway to obsolescence, and an effective change in value perception, it is clear that fashion products pose a risk of not just lost sale opportunity, carrying costs and margin cuts, but also pileup of unsold products as landfills. Growing concerns on environmental hazards and increasing focus on lifecycle management of products, the concepts of remanufacture and recycle are repeatedly arriving center stage. Researchers hence increasingly focus on decisions to be made at both beginning a well as end of product lifecycle. Durable goods like consumer electronics and automobile spare parts have been increasingly studied with respect to their possibility of remanufacture. For example, Mangold conducted an assessment survey to arrive at a material flow analysis to develop a representative set of end-of-life pathways in order to better understand the flow of e-waste within the end-of-life management industry in the USA [19]. Such practices of remanufacture, however, are not too prevalent for fashion products. A quick review of current businesses engaged in remanufacture of obsolete fashion goods presents a rather encouraging picture for custom-made and customer-to-customer (C2C) sale points. It is often noticed that deconstructed garments (the popular nomenclature for remanufactured clothing) are restricted to couture garments, which largely have a higher shelf life than their other, more inexpensive counterparts. The channels that these garments adopt for reaching to the consumers are also largely restricted to social media, wherein the products are sold through orders accepted on Facebook or Pinterest. However, the presence of deconstructed garments for sale by popular brands, in the mass-market segment, has not been documented, apart from its presence on Web sites like Etsy. The operational costs notwithstanding, it may also be prudent to observe if the astute fashion consumer may have any reservations with respect to his/her acceptance of the product. It is here that the nature of the consumer takes center stage, and the innovative consumer becomes an important stakeholder.

Within the paradigm of an obsolete fashion product and its varied perceptions, some consumers of fashion differ from other products due to their propensity to pick products faster than their counterpart. Robertson suggests that consumer innovators (the first people within a community to buy new products) reflect more favorable new product attitudes and are more swayed by newness appeals than later buyers [20]. These consumers not only readily accept newer fashion products, but also, due to their nature as opinion leaders and strong social influencers, may be able to persuade the fashion followers to accept deconstructed garments. Innovativeness has been measured using the time of adoption method, which segments adopters into groups ranging from innovators, early adopters, early and late majority to laggards. Many studies have been devoted to understand the characteristics of such innovators; with an effort to arrive at attributes that can define him/her, as against a follower, on more absolute terms than measuring the time of adoption studies by Goldsmith et al. and Pastore clearly define that highly innovative people tend to take more risks, show greater social participation, have higher opinion leadership scores, be more knowledgeable about new products are more involved in the product category, have greater media exposure, and be heavier users of the product category [21, 22].

19.4 The Conceptual Framework

The consumer acceptance of deconstructed garments, hence, needs to take these constructs into consideration. Consumer purchase intention of these products, specifically in the mass-market segment, needs to be a fine interplay of the perceived value of these products, which, further-on, are influenced by the innovativeness of the consumer, his perceived monetary sacrifice and the perceived quality of the product.

These parameters are measurable, tangible, and clearly defined. The interrelationship of these factors is conceptualized as below. It is postulated that the innovative consumer will have a different perception of the value of fashion merchandise (measured as “Perceived value”), as compared to a follower, when offered with a deconstructed fashion product (measured as “remanufacture”). This value perception, in turn, affects the Intention of the consumer to purchase the product (measured as “Purchase intention”).

19.5 Research Methodology

The selection of a research approach involves “plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation” [23]. This study involves the application of two distinct control variables, which are expected to affect the exogenous (dependent) variables of perceived value and purchase intention. Since it seeks to measure the intervention of an outcome, the study focuses on an experimental design to arrive at its outcomes. The said experimental design selects participants by random selection or random sampling. This study intends to map the effect of garment deconstruction on the perceived value of a clearly defined consumer demographic, which most likely needs a convenience sample with a naturally formed group. Hence this study involves a quasi-experiment, posttest only design. The group is divided and the stimulus (Deconstruction) selectively given to each group. The participants are evaluated based on their responses to a questionnaire that measures the defined constructs.

19.5.1 Selection of EOLC Garments

In a short shelf life product category like fashion apparel, garments reach their obsolescence as early as in two weeks of introduction to stores, facilitated by the fast movement of trends and changing consumption patterns. A retailer catering to a mid-market and a sub-premium consumer segment offered SKUs from their unsold stocks, which were due to be liquidated by selling in bulk to a liquidator. Among these, a Men's basic 5 pocket jeans (in Denim, original MRP 4999) and a Men's basic shorts (original MRP 2999) were selected for the experiment.

19.5.2 The Process of Deconstruction

The garments were opened at their seams to provide the separate components for the deconstruction activity. The components (or panels, as referred to in garment construction) were draped on a standard size women's dress form to arrive at a silhouette acceptable to the brand's design language. It is pertinent to note that since the process of deconstruction involves loss of some fabric at the seam level, Men's garments are conceptualized as newer products for women's wear, to enable correct sizing (Fig. 19.1). The process is elaborated in the flowchart below:

The Deconstructed garment was a Women's jacket, waist-length at front and elongated at back (Fig. 19.2). The images for this product are given below:

Fig. 19.1 **a** Original garment, **b** opening the seams and placement of panels, **c** draping on a standard women's dress form

Fig. 19.2 Deconstructed garment women's Denim jacket

19.5.3 Conducting the Experiment

The participants for this experiment were students from a well-known university, pursuing undergraduate and postgraduate study. The university offered varied courses, hence the participants were from a heterogeneous community pursuing courses in both design as well as known-design subjects.

The participants were divided into two groups—Group 1 consisted of consumers who were aware of deconstructed garments, and were exposed to such garments through social media. Group 2 consisted of consumers who were unaware of deconstruction as a process. The study was conducted on 30 participants, equally divided into two groups based on their awareness of deconstructed garments, making "Product knowledge" the manipulated variable for the experiment. They were shown both the garments—pre- and post-deconstruction, and requested to respond to a structured questionnaire. The itemized questionnaire measured their fashion innovativeness, perceived value, and purchase intention and was derived from preexisting scales obtained from a detailed literature review.

19.6 Findings

The responses from the participants were tabulated and analyzed for an association between the innovativeness of the consumer, prior knowledge about deconstruction, his/her perceived value toward the deconstructed garment and his intent to purchase (Table 19.1). The results are collated and tabulated below.

Table 19.1 Results of regression of innovativeness and perceived value

Dependent variable = perceived value	Unstandardized coefficients (B)	Std. Error	Standardized coefficients beta	t	Sig.	R square	F	Sig.
(Constant)	−3.023E-18	0.116		0.000	1.000	0.624	44.746	0.000[a]
Innovativeness	−.790	0.118	−.790	−6.689	0.000			

(a) Consumers who had prior knowledge about deconstruction did not vary in the intent to purchase the deconstructed garments, as compared to the consumers who were aware about the same ($p = 0.797$, $p > 0.05$). It is also interesting to note that the awareness about deconstruction did not affect the consumers' perceived value of the deconstructed garments ($p = 0.749$, $p > 0.05$) (Table 19.2). Deconstructed garments were perceived well and created an intent to buy, among consumers, irrespective of their prior knowledge about the concept.

(b) However, Table 19.3 indicates that there exists a significant relationship between the innovativeness of a consumer and his intent to purchase the garment ($p = 0.00$, $p < 0.05$). A more innovative fashion consumer is more liable to purchase a deconstructed garment than a fashion follower. An R squared value of 0.635 between these two variables as indicated in Table 19.3 also explains that nearly 64% of the intent to purchase is explained by the innovativeness of the consumer

(c) Likewise, Table 19.1 indicates that there exists a significant relationship between the innovativeness of the consumer and the perceived value of the deconstructed garments ($p = 0.00$, $p < 0.05$). A more innovative consumer is likely to perceive a deconstructed product as of a higher value, as compared to a fashion follower. An R squared value of 0.624 also indicates that nearly 62% of the variances in perceived value are explained by the innovativeness of the consumer.

Table 19.2 Correlation between prior knowledge about deconstruction

	Innovativeness	Prior knowledge about deconstruction
Purchase intention	−0.797 ($p = 0.000$)	
Perceived value	0.749 ($p = 0.000$)	−0.026 ($p = 0.893$)

Table 19.3 Results of regression

Dependent variable = PI	Unstandardized coefficients (B)	Std. Error	Standardized coefficients beta	T	Sig.	R square	F	Sig.
(Constant)	3.483	.161		21.691	.000	**0.635**	46.888	**.000[a]**
Innovativeness	**−1.119**	.163	−.797	−6.847	.000			

Innovative consumers surely take the lead in forming a higher value perception and an intention to purchase deconstructed garments, making them ideal flag bearers for promoting their purchase and consumption. Brands dealing with excess and unsold inventory need to target fashion leaders, in their quest to create a favorable perception of deconstruction. However, it is heartening to note that prior knowledge of the concept of deconstruction is unlikely to change the value perception or the willingness to purchase—this puts the onus on the designer in creating product through the process of deconstruction which can appeal to a fashion consumer, irrespective of his viewpoint on the remanufacture process. With increased focus on sustainable production, environmental awareness, landfill management, and lifecycle of consumer goods, fashion can surely pave way for re-utilizing obsolete and liquidation-ready merchandise, and derive commercial and ecological value.

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Chapter 20
Modelling of Causal Relations in Human Pathophysiology for Medical Education and Design Inspiration

Soumya Singh, Aditi Makharia and Amaresh Chakrabarti

Abstract While knowledge of general biological phenomena attracted much attention for supporting bio-inspired design, knowledge of biomedical problems has hardly been explored. However, this too can support training, diagnosis, and design. For instance, clinical expertise development during pre-clinical training depends on biomedical knowledge organized as complex causal structures in the clinician's mind. The accuracy of diagnostic expertise depends on the richness of these causal structures. Knowledge of medical problems can also act as stimuli for ideation for a designer. However, there is a lack of a standard structure for the depiction of causal relations. The proposed model for causal relations in human pathophysiology aims at describing the causes and consequences of diseases to aid pre-clinical medical education and design inspiration. The model is based on a 'systems thinking' approach to studying a complex system, where the entities of a biological system, arranged hierarchically in multiple levels, interact to fulfil a function. The model incorporates three levels of description of a disease: *Hierarchical component-issue* level, *issue inter-relation* level and *issue description* level. The first level incorporates knowledge of the hierarchy of all related components and issues occurring in a disease. The second level captures relational knowledge among the issues. The third level provides data at the most detailed level of human biology (biochemical processes) for each issue in a disease. Each level is accompanied with textual descriptions and images to aid comprehension. A qualitative survey is conducted with medical students and faculty members to assess the usability of the model.

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20.1 Introduction

Knowledge of problems from the medical domain can serve multiple purposes: better training of clinicians, diagnosis of illnesses, improved design of devices for supporting such diagnosis or their remediation, and as knowledge that can act as biological stimuli for ideation of novel engineered systems. In all of these, understanding of diagnostic knowledge plays a critical role. The objective of this paper is to develop better models for organizing this knowledge, so that the above purposes can be supported. The immediate aim is to support understanding, in clinicians, of problems in the medical domain.

The organization of knowledge in a physician's mind has been investigated for decades, resulting in various theories. One such theory [1] states that expert physicians initially acquire biomedical knowledge during the period of medical education. This knowledge is developed and stored as causal structures which lead to probable diagnoses. The accuracy of these diagnoses directly relates to the accuracy of the biomedical knowledge-rich causal models developed.

According to [2], medical students acquire medical knowledge and develop expertise during their training and work over a number of stages. During the first stage, they acquire complex knowledge of causes and consequences of diseases (pathophysiological knowledge), and store this in the form of causal networks during their medical training. The second stage involves encapsulation of this knowledge, where experiences with real cases transform the causal structures into narrative structures called 'illness scripts' that are high level but simplified causal models involving clinically relevant information (signs and symptoms). In the final stage, acquisition of experience with actual patients leads to the formation of instantiated scripts, based on the episodic knowledge of previously analysed patients.

The first stage, according to [3], is significant since the accuracy with which an expert formulates a diagnosis is strongly dependent on the 'extent to which the expert possesses rich causal biomedical knowledge structures in memory' [3]. No standardized structure for such knowledge is currently available in literature. Thus, there is a need for organized structures that can aid in constructing problem representations, which can be activated and processed in a conscious fashion while dealing with a case, hence decreasing the considerable time such a process takes.

In this paper, a representation for pathophysiological knowledge as a causal model is proposed; it aims to capture all relevant data for diagnoses after pre-clinical training is complete. This structure, if provided to students during their pre-clinical training, should enhance their ability to learn, capture and store such data and act as an important factor in medical expertise development.

20.1.1 Background

Complex systems abound in natural and engineered worlds. Understanding how complex systems work is a precursor to satisfying human curiosity and needs, and is critical to both analysis and synthesis. It helps answer questions such as ‘How does inhalation of pollen lead to severe allergic reactions?’ [4], providing bases for diagnostics, testing and design. A complex system is characterized by multiple components arranged in multiple levels that interact with one another to function as a whole. An example is the human body, with multiple, interacting organ systems that are made of respective organ-, tissue- and cell-hierarchies. Interactions of these components in the human body lead to the aggregate functioning of the system [5].

In order to grasp the complete picture of a complex system, it is necessary to understand the interactions of the phenomena at various levels of the system. A key research issue in this field is finding ways to support learning of such systems. This dates back to the concept of general systems theory [6]: ‘Since the fundamental character of the living thing is its organization, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena. This investigation gives us no information about the coordination of parts and processes. Thus, the chief task of biology must be to discover the laws of biological systems (at all levels of organization)’ [6]. ‘Systems thinking’ is a discipline that focuses on understanding system-level functioning of interacting parts.

Systems thinking has been used as a metacognitive tool for enhancing biology education by hierarchically structuring knowledge [7], thereby reducing the need for acquiring large quantities of biological facts. The study concluded that this approach enabled students acquire the competence of thinking backward-and-forward between levels. Systems thinking can thus provide coherent understanding of biological phenomena by addressing both horizontal (relation at a level of biological organization) and vertical coherence (relation between levels). The work suggested that systems thinking requires developing strategies for abstract and complex biological topics. The level of biological organization is a key feature of our proposed causal model of diseases, as has been well supported by evidence from past studies.

In the past, causal models for diseases, represented as causal relationships among the components of the biological systems, have been developed and implemented in computer programs for diagnostic reasoning. One example is (CASNET) Causal-Associational Network, where causal knowledge of a disease is represented by three types of data elements: observations of the patient; pathophysiological states; and disease categories. The program uses a bottom-up approach for diagnosis in which causal pathways form a link between observations to the pathophysiological states which in turn are linked to disease states. A similar inter-level causal pathway relational structure is represented in the ABEL system that forms a patient-specific causal model with three levels of abstraction; the lowest level with the highest detail is pathophysiological, linked to the intermediate level and followed by the simplest level, the clinical level. Another tool, CHF advisor, represents the disease congestive heart failure; it has two modules: a diagnostic module that searches for causal chains of undesirable effects; and a treatment module that inspects these causal chains to find opportunities for therapeutic intervention [8]. Such work supports the use of inter-level causal models for representing diseases. Our research focuses on a novel causal pathway for modelling diseases. It has been adapted from earlier work on a framework for representing causal pathways in a mechanical system [9–11].

20.1.2 Proposed Model

In the causal model for diseases we proposed in this paper, the complexity of the human body super-system is represented utilizing a hierarchical tree that classifies all the entities in the body [12, 13]. We incorporate systems thinking by taking into account the interconnection among entities at the lowest level (biomolecules) to the highest level (human body), which together results in a function. Causal relations must be studied in order to gain an insight into the processes that govern a function [14]. The proposed structure for causal relations of diseases is an amalgamation of the human body hierarchical tree and three levels of abstraction of the disease.

The human body is composed of several interacting organ systems (Fig. 20.1). Each organ system comprises a hierarchy of ‘Organs’ (rounded rectangle), ‘Tissues’ (rhombus) and ‘Cells’ (oval). Each organ has a hierarchy of sub-organs that are made of tissues having their own hierarchy of sub-tissues, which in turn are composed of cells. Figure 20.1, for instance, represents a part of the integumentary system.

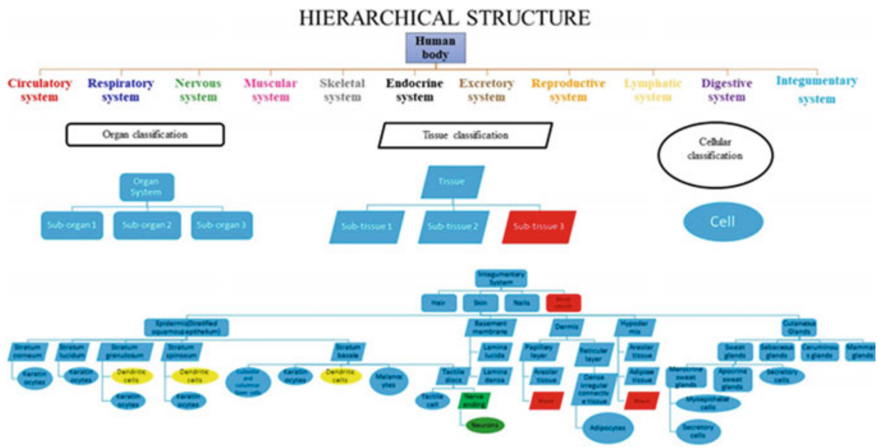

Fig. 20.1 Hierarchical classification of human body and its components partial classification of the integumentary system depicting the ‘skin’ and its components

Each organ system is colour-coded, see Fig. 20.1. As systems interact at multiple levels, a component of one system may be part of other systems; this is displayed by their respective colours in the hierarchy. For instance, sub-tissue 3 belongs to the circulatory system (red), but is also a part of the integumentary system's hierarchy (blue).

The representation of a disease pathophysiology has three levels that provide increasing levels of detail of the disease: hierarchical component-issue; issue inter-relation; and issue description. These are explained using the disease 'Basal cell Carcinoma' (BCC) that occurs in the integumentary system of human body [15, 16].

At the hierarchical component-issue level, Figure 20.2, the human body structural hierarchy consists of the whole body, organ systems, organs, tissues and cells. This view relates the issues occurring in the disease at each hierarchical level. The issue propagates up through the hierarchical levels and is observed in the human body (main system) as symptoms. 'Effects on OTC' (organ, tissue and cell) lists all the issues occurring in the progression of the disease (major issue) in the organs, tissues and cells. All of these issues cumulatively result in the 'Effects on Organ Systems'.

This is represented by an arrow directed from 'Effects on OTC' towards 'Effects on Organ System'. 'Effects on Organ System' lists the organ system name and the end effect of all the issues on the respective system. 'Effects on Human body' lists the symptoms of the disease as seen in the body, which is the result of the effect of issues on the organ system. This is represented by an arrow directed from 'Effects on Organ System' 'to 'Effects on Human Body'. Further, a short disease description gives an overview of the disease. An image is also provided to aid comprehension.

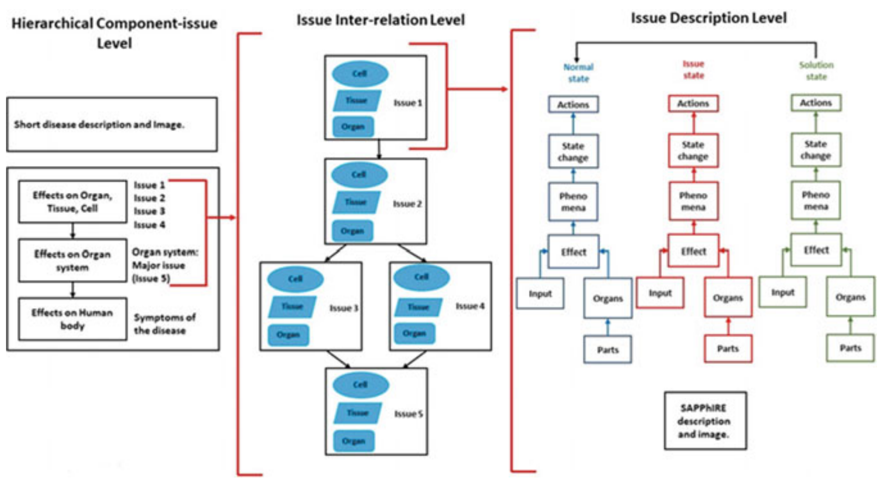

Fig. 20.2 General structure of the three levels of abstraction

BCC is characterized by issues: ‘Mutation’, ‘Deregulation of Sonic-hedgehog pathway’, ‘Unrestrained cellular proliferation-1’ and ‘Unrestrained cellular proliferation-2’, as listed under ‘Effects on OTC’ (Fig. 20.3). Their effects are observed in the integumentary system as aggressive BCC (‘Effects on Organ System’). ‘Effects on Human body’ lists the symptoms in the body as ‘Skin lesions, lumps, ulcers, itching’, a result of aggressive BCC from the issues listed under ‘Effects on OTC’.

At the Issue Inter-relation level. Figure 20.2, all the issues (Effects on OTC) occurring in the progression of the disease (major issue) are linked sequentially using a flow diagram, along with the respective organ, tissue and cell in which it occurs. As shown in Fig. 20.4, ‘Mutation’ (which occurs in ‘keratinocyte’ cells present in the ‘stratum basale’ tissue of the organ ‘skin’) leads to ‘Deregulation of the Sonic-hedgehog pathway’ and then to other issues as indicated by the direction of the arrows.

Using the SAPPhIRE model of causality [9], the Issue description level (Fig. 20.2) describes the biochemical details of a pathophysiological process with elaborate descriptions of each issue: ‘issue state’ (red), ‘ideal state’ (blue) and ‘solution state’ (green). The model consists of seven constructs: state change, action, parts, phenomenon, input, organs and effect. Each construct within the model deals with a specific aspect of the working of a system, thereby describing the functionality of the system. The models are accompanied by a description of the issue being illustrated using the SAPPhIRE models. Images and diagrams are provided as relevant.

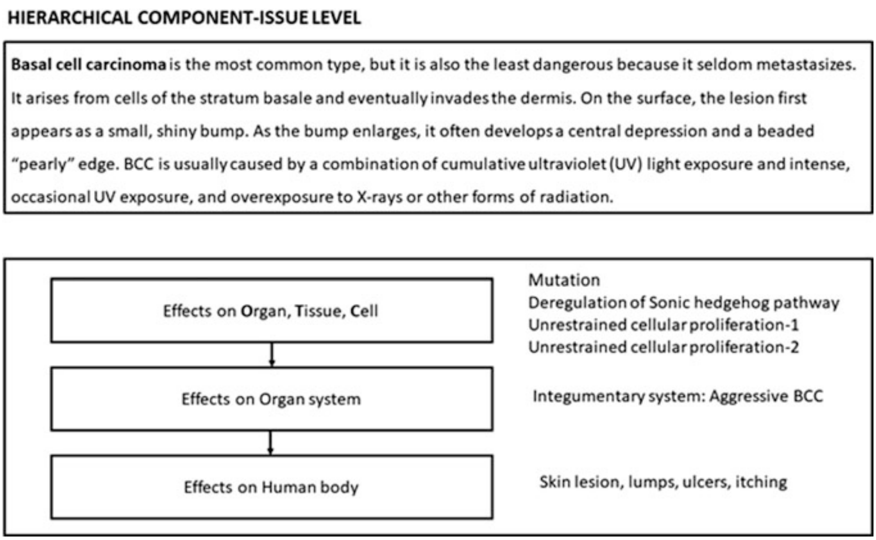

Fig. 20.3 Hierarchical component-issue level for BCC

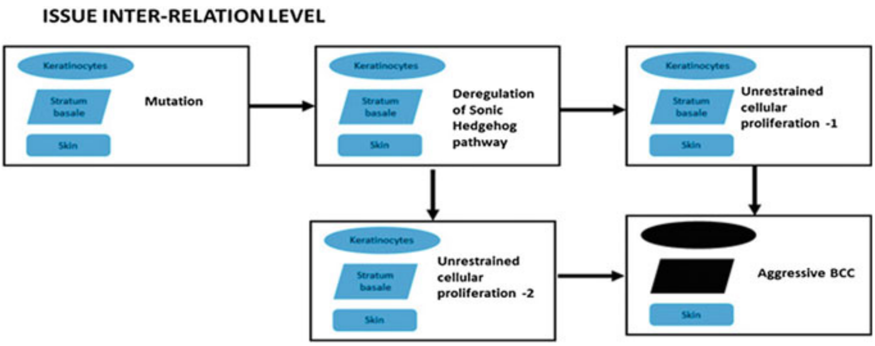

Fig. 20.4 Issue inter-relations level for BCC

For example (Fig. 20.5), the issue state SAPPhIRE (red) describes an issue 'Unrestrained cellular proliferation-1', read as follows: Consider a human body having parts keratinocytes, stratum basale and skin with specific biochemical components. The properties and conditions necessary for the issue to occur are the organ: abnormal activation of PDGFRA gene. This, with overexpression of PDGFRA protein in the cells as input, activates the binding kinetics and the law of mass action [effect], which causes signal transduction: overexpressed PDGFRA up-regulates RAS-MAPK1 pathway which down-regulates FAS and Caspase 3 [phenomenon], which leads to the increased inhibition of apoptosis [state change], interpreted as unrestrained proliferation of basal cells of skin [action]. The ideal state (blue) depicts the desired functioning of the pathway. The issue can be resolved by an existing solution state (green), where drug cyclopamine inhibits a particular step of the irregular pathway.

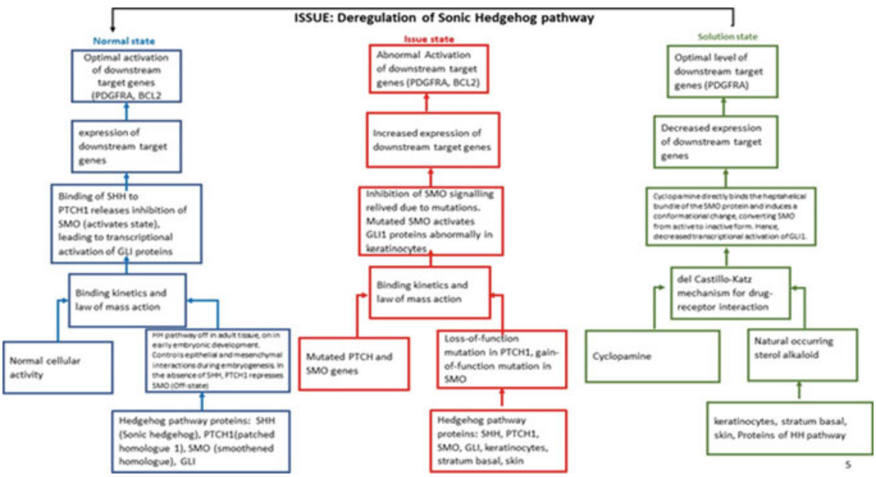

Fig. 20.5 Issue description level for deregulation of Sonic-hedgehog pathway in BCC

20.1.3 Evaluation

A preliminary survey study was conducted with ten subjects (third year medical students) to test the potential of the model as a means for aiding their comprehension. The subjects were given the structured model for ‘basal cell carcinoma (BCC)’ disease to study. They were provided the following survey questions:

Question 1: If given an option between reading scientific literature/textbook related to BCC, studying the disease using the representation, or both (the textbook supplemented with the representation) which one would you prefer and why? This question helped to understand the preferred methods of student of the students.
Question 2: According to you, how understandable is the causal representation of diseases? This question checked the understandability of the proposed structure as an instrument for studying a disease and its pathophysiology during medical education. The students were asked to rate the understandability based on a Likert scale.
Question 3: How helpful will this structure be for medical students interested in learning about a disease? The aim was to sense the opinion of medical students in the utility of the model in studying pathophysiology, rated using a Likert scale.
Question 4: Does the structure capture all the relevant details, required to study a disease? Rate its sufficiency. This was to gauge the level of detail needed for pathophysiological study as seen by medical students, and efficacy of the structure proposed, rated using Likert scale. The next question aimed at general feedback.
Question 5: If you could make any modifications/additions to this representation, what would you suggest? Any other feedback?

20.1.4 Results

The results from the survey are discussed below.

The first question received answers such as ‘I would definitely use this representation for study as it helps create a mental picture of the disease being discussed’ and ‘I was able to visualize the disease in an easily memorable way but I would also need my textbooks for theoretical study’. Similar comments received indicate that the subjects appreciated the aid provided by the representation provided in understanding the pathophysiology of the Basal Cell Carcinoma. The statements were largely on the positive side and in favour of using the representation.

The response to the second question was Likert scale based (Fig. 20.6). Five options were provided to the subjects: ‘Not at all understandable’, ‘Slightly understandable’, ‘Moderate’, ‘Good’ and ‘Excellent’. Out of the ten subjects, six marked the representation as ‘Excellent’, three marked it as ‘Good’ and 1 marked it as ‘Moderate’. This indicates that the majority felt the representation was easy to comprehend.

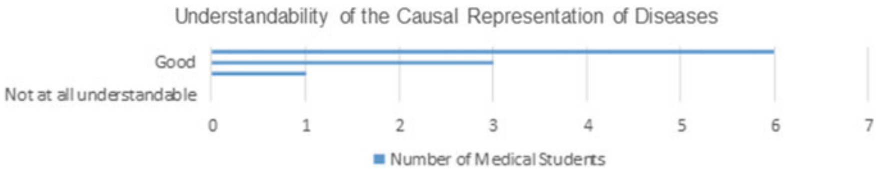

Fig. 20.6 Response to the second survey question

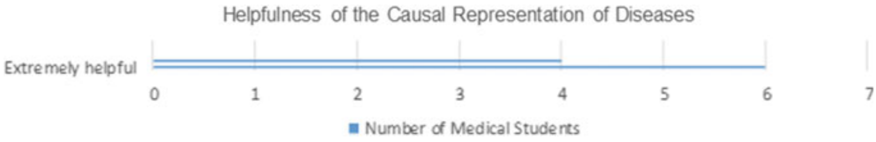

Fig. 20.7 Response to the third survey question

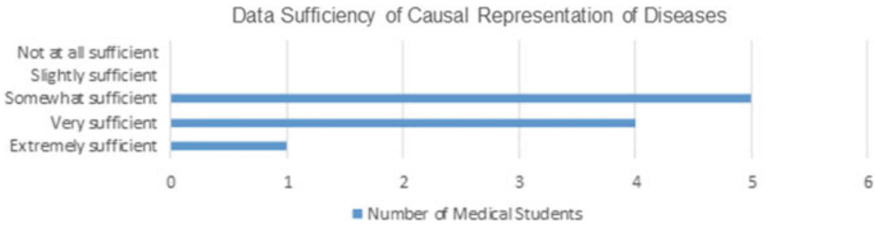

Fig. 20.8 Response to the fourth survey question

Results for the third question are given in Fig. 20.7. Once again, the subjects responded rather positively, with four rating it extremely helpful, and the rest as good.

The fourth question received an equal number of moderate and positive ratings. This indicates that the details incorporated in the paper have potential for aiding a detailed understanding of the disease. The results are given in Fig. 20.8.

The final question asked for general feedback on the structure and what modifications they deemed suitable for increasing usability. Most of the subjects stated that the structure was quite comprehensive as is and would be useful as a teaching aid.

20.2 Summary and Conclusions

It is argued by [1] that '… modern curricula emphasizing the organization of disease processes around organ systems are more effective than the classic Flexnerian curriculum, which emphasizes the teaching of biomedical and clinical knowledge as different phases in the medical curriculum'. The preliminary results obtained from the survey conducted for the proposed causal model render some support to this. As stated in [17], even though recently developed tools and databases contain extensive knowledge of the biochemical and molecular level processes, it is not sufficient to study only molecular level data regarding processes in biology, as all the higher levels of organization like cells, tissues and organs. are an equally important part of the biological system. Thus, a system-level, causal approach to understanding is necessary and should be a major goal for assimilation of biological knowledge. Given the small sample size and the few questions used in the preliminary study, it is difficult to draw any substantial conclusion, except for that the results encourage taking up more extensive evaluation of the model with more subjects and more test cases, leading to further development of the model into a tool for comprehension and interpretation of the pathogenesis of a disease, with the intent of helping retain the information in memory and reproduce when required.

As suggested in [18], if medical students are given a detailed knowledge base of clinically applicable data, they are able to flexibly apply and transfer this knowledge more efficiently in a clinical situation. Since the proposed causal structure is aimed at providing such knowledge in detail, it could aid alleviation of the common transfer problem that students face while applying classroom-acquired knowledge in real-life clinical applications. Another potential application is for medical teaching staff to use the structure as a supportive tool for delivering pathophysiology lectures.

The purpose of causal models is not restricted only to education. As echoed in previous work [2, 8], causal models might be useful for physicians as well. In a clinical scenario when physicians face a complex or unusual case, they tend to revert to analyzing the disease structure as detailed biomedical causal networks. Further, causal models might be helpful when a physician needs to provide an explanation behind a decision, as also indicated by some of the responses in the survey.

A further limitation of the study has been that the survey has been used to primarily gather retrospective feedback, rather than as a comparative study of the performance of medical students with pre- and post-tests. As mentioned earlier, a further issue has been the low number of participants and test cases in the survey; this has been due to lack of availability of medical students for the survey. Extending these is a part of future work. Another drawback is that accurate anatomical knowledge of position needs to be incorporated into the structure tree of the human body so that relations among components can be accurately described, e.g. information like 'part of', behind, etc. must be given and is not incorporated in the current representation.

Overall, the positive feedback obtained in the survey reported in this paper indicates that the proposed structure for causal relations in a disease has potential for possible implementation in modern medical curricula as a supportive tool for aiding learning.

Further, the work, we argue, has potential to aid study of mechanisms of biological systems and support engineers in using biomechanics for design. It could be used, for instance, to provide background knowledge for designing biomedical systems, or as stimuli for designing engineered systems, much the way general biological knowledge has been used in bio-inspired design. However, these are yet to be tested.

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Part IV
Design Aesthetics, Semiotics and Semantics

Chapter 21
A Preliminary Study on Identifying the Potential Core Values for Product Branding Based on Malaysian Keris Characteristics

Azrina Zizal Abdul Aziz, Shahriman Zainal Abidin and Rusmadiah Anwar

Abstract This paper discusses in profiling Malaysian *keris* DNA and properties, to identify the core values and to build emotionally sustainable heritage brand recognition with the Nostalgia Sentimental Values (NSV) towards product design. In this research, the researcher's focus is to build an emotionally sustainable Malay heritage by profiling Malaysian *keris* DNA & properties as one of its core value towards nostalgic sentimental values in brand recognition. To do so, the research requires a focus on building characteristics from profiling Malaysian *keris* properties and stories in tandem by designing a product itself. Hence, to establish Visual Branding Characteristic (VBC) as the core value of the product design where the abstract characteristic is part of the Malaysian *Keris* properties which can communicate through aesthetic elements either semantically or syntactically as a Visual Brand Language (VBL) cohesively building its Nostalgic Sentimental Values (NSV) as the core values in brand recognition towards Malaysian products. Eventually, it can be used as a future reference and as a benchmarking guideline in branding Malaysian identity towards product design.

21.1 Introduction

Economic success is driving innovation constantly resulting in brands being repositioned frequently. In this research, the Malaysian *keris* in terms of its overall design and is gradually dissecting its "deoxyribonucleic acid" (DNA) [1] and properties layer upon layer to sums out the ground visual platforms of its DNA and

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properties semantically and syntactically to be able to identify the core values in brand recognition—which in due time enable to be used as a guideline or to be able to benchmark one of the core values in theMalay Culture Heritage brand recognition towards Malaysian product design brand's identity [1]. The core value of the brand recognition is where the abstract characteristics and properties are part of the Malaysian *keris*.

DNA and properties cohesively communicate through the aesthetic elements of Malaysian product design. As a result, it will trigger the Nostalgia Sentimental Value (NSV), ultimately able to position the products as a perpetual design by cohering and connects the past, present and future in the new product design. Identification of the core value in the VBL in which is achieved by effectively integrating the essence of the Malaysian *keris* DNA and properties towards product design unified with the abstracts attributes. Nevertheless, if it is done correctly, the identification of the core values in brand recognition will be able to build the brand identity. Hence, the core values in brand recognition will become potent heritage evident message through product design by successfully integrating the past, present and future. The overall thrust of these studies is to test the hypothesis and the success of the implementation. The concept of study in identifying the Malaysian *keris* core values in brand recognition towards Malaysian product design is by measuring the abstract concept or intuitive gestalt [2] of the Malaysian *keris* in relation to heritage brand recognition identity in tandem to evoke the NSV towards product design. The researcher needs to define the concept by operationally orchestrate measure and break it down to observable and measurable behaviours to delineate the identification of Malaysian keris DNA and properties core values in brand recognition in tandem to its NSV towards product design.

21.2 Literature Reviews

21.2.1 Malaysian Keris Artefacts Type and Structure

Keris originated in Peninsular Malaysia (*Tanah Melayu*) and only can be found within the Malay Archipelago [3]. There are several design styles of *Keris* in the Malay heritage treasures [4]. *Keris* has two separate parts known as blade (*Bilah*) and dress (Sarung) and hilt (*Hulu*). These components [5] (see Fig. 21.1) become the main structure of *keris* in any *keris* design.

In Ahmad Mu'ati book entitled "Introduction to *Keris* Semenanjung", 2016—Ahmad has found that Malaysian *Keris Semenanjung* comes in variation types, differs from every Malaysian district and has its own history, usage function and purposes [6]. The types of Malaysian *Keris* are *Keris Tajung, Keris Choteng, Keris Charita, Keris Debek, Keris Bugis Semenanjung, Keris Sundang, Keris Panjang, Keris Selit, Keris Alang, Keris Melela/Malele, Keris Tok Chu, Keris Semenanjung, Keris Pandai Saras, Keris Anak Alang* and *Keris Beko/Beka.* In his research, he

Fig. 21.1 Types of *keris*

managed to introduce and elaborate the *Keris* Semenanjung and discussed a general purpose of each type of *Keris Semenanjung* [6], its history and design according to their origin's state districts and identification of *keris* types followed by its origin's district with culture clan's influences within Malaysia. However, according to the researcher's interview session with Abdul Mazin Abdul Jamil, 2018 as the royal keris maker, he strongly elaborated that there are only three primary types of *Keris Semenanjung*—which are *Keris Alang, Keris Hukum/Kuasa* and *Keris Pukal* [7]. The rest of the *keris* types evolves and developed from these three primary keris which is then given a new name as mentioned by Ahmad.

Hence, in the efforts of exploring new avenues, a metallurgy test was conducted on the *keris* blade to determine the metal used, analyse the hardness of the *keris* blade and seek out alien elements within its manufacturing process [8] by Khamis Mohamad in his book titled "*Keris* The Masterpiece", 2017. The *keris* is synonymous with the Malays, and history has revealed that the sovereignty of a country/kingdom/sultanate/status-quo is determined by the magnificence that lies within the *keris*, and *keris* represents the honour or the *"Jati Diri*" of the Malays [8]. Khamis introduces the *keris* as a masterpiece and a depth understanding of the scientific metal analyses and its structure have been analysed through high magnifications test and destruction test material composition on the *keris*'s blade from various origin types. Except that in his explanation, he mentioned about the masterpiece of *keris* variation throughout the Malay's regions such as Malaysia and Indonesia. Khamis also discusses about the *keris* background, culture influences of the *keris* structure differences, especially its philosophy and functionality [6] within the Malay regions especially the importance of the *keris* blade's materials and its significance to the Malay culture that dignifies one's status-quo and ranking within the ancient Malay societies.

Nevertheless, Zainuddin Mohammad, the curator of Selangor Museum, 2007, also discusses the extensive overview of the overall Malay's weapons within Malay Archipelago regions from various point of perspectives from the identification differential of each weapons, the evolution history of every weapons since the Neolithic, Mesolithic time to these days in terms of *keris*'s materials, usage, the making process and the weapons philosophical approach [9] (Fig. 21.2).

Fig. 21.2 Basic parts of *keris* design

Meanwhile in the brand recognition towards the Malaysian product design identity, it is essential for the designers to relate the historical values and Malay heritage culture to tandem its values [1]. As Temporal has quoted that "Sometimes when brand has reached a point where consumers are almost taking it for granted and sales are stagnant or worsening, instead of trying to create an entirely new positioning, it might be worthwhile looking as successful strategies from the past, or evoking nostalgia values" [10]. Therefore, it is an evident that the researcher would like to point out how important re-positioning [11] our nation brand identity towards product design by bringing the old to new product development by integrating the historical values and story behind our Malaysian product designs [12]. By doing so, not only we could able to uplift Malaysian brand itself, but concurrently able to uplift our Malay culture heritage and treasure values to the global eyes, as similarly have been done by the Scandinavian, Japanese and Korean country on today product re-positioning to global market. This dilemma has been disputed too among our local designers and scholars on re-positioning our Malaysian product design, in which until today, we still have dilemma in finding our Malaysian brand identity [13].

The brand meaning [14] shows how he reframes the steps for building a strong brand identity by amplifying the importance of establishing the proper identity in brand in giving its meaning, eliciting the correct brand response and the importance to forge appropriates relationship between brand and demography audiences.

In Keller's brand resonance pyramid [14] (Fig. 21.3), Keller identifies areas that need effective communication and empathy which is one of Keller key values in brand imagery deals with brand attempts to communicates psychological and social needs, which is an intangible aspect of brand that are usually chosen by consumers due to its perfect fit to demographic profile or that which has psychological and association appeals towards their personality traits and outlook of life (culture,

Fig. 21.3 The brand meaning framework: Keller's brand resonance pyramid—a customer-based brand equity

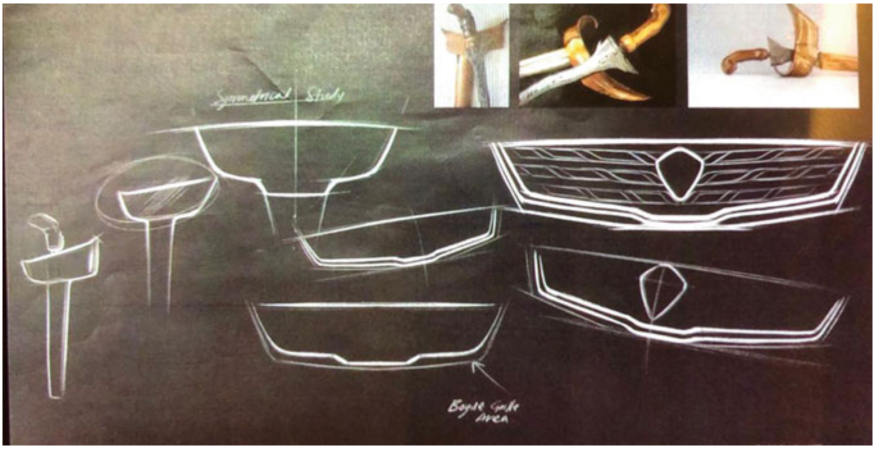

Fig. 21.4 The brand meaning: design development sketches stage inspired by Keris heritage integration exploration sample

conservative, creative, heritage, etc.) which is applicable in integrating the *keris* core values onto new product design.

Exploration in integration of the Malaysian *keris'*s *sampir* characteristic semantic traits onto the Proton automotive front grill design to evokes the Malaysian NSV on its design as the brand identity (Fig. 21.4) in reference to the Keller's brand resonance pyramid. Initially, the item used in represents local identity in Proton car model Preve which was inspired from Malaysian nature; the Malayan tiger metaphor seems to be given a promising attributes to the characteristics of the styling for the car design [1]. However, most Proton designers believed that the uses of the significant Malaysian characteristics as identity are important in correlation with shape character traits through semantic and semiotics properties of selected item in brand identity as a source of reference embodied agents make DNA styling interpretations stand substantial from ambiguity—hence *keris* semantic able to built connections between shape character traits and form brand language functions at the higher impact in triggering NSV [15].

21.3 The Conceptual Framework

These proceeding steps in Profiling The Malaysian *Keris* DNA & Properties: In Identifying The Core Values In Brand Recognition Towards Malaysian Product Design, as they suggested by exploring the design DNA of product could represent brand and identity [13]. The exploratory with the intention to develop Malaysian brand and identity [11] is able to help the designers to uncover the "deoxyribonucleic acid" (DNA) based on Malay culture influences either semantically or syntactically [16] in terms of its material, structure, motive elements, designs, culture influences, etc. [17].

Referring to Keller's brand resonance pyramid [14] as in Fig. 21.2, in finding our Malaysian product design brand identity is like a building block that plays a major role in sculpturing our Malay culture heritage values in tandem to the product design. It is necessary for product designers to diligently craft their creativity [16] in the exploration by integrating the Malaysian *Keris* DNA and properties by identifying its core values in brand recognition towards Malaysian products. *Keris* in the Malay culture and heritage has always been the upmost empowering artefacts among the ethnic, as it dignifies sovereign, power, status-quo, pride, weapon [4] and religious rituals [18] which also has been a long history of spirituality, magic and mythologies surrounding it [19].

In this work, a participative observation and interviews [20] with the keris makers within Malaysian Malay regions in the *keris* making process throughout Design Protocol Analysis [16], especially in understanding the keris structures, decorative, culture influences, semiotics [21] and materials [18] of the Malay heritage *Keris* artefact. The next phase is to conduct fact-finding analysis using focus groups [21] to ascertain results by integrating the old and new properties in relation to brand characteristic of product design that would sustain the nostalgic sentimental values in contemporary approached of product design. The respondents

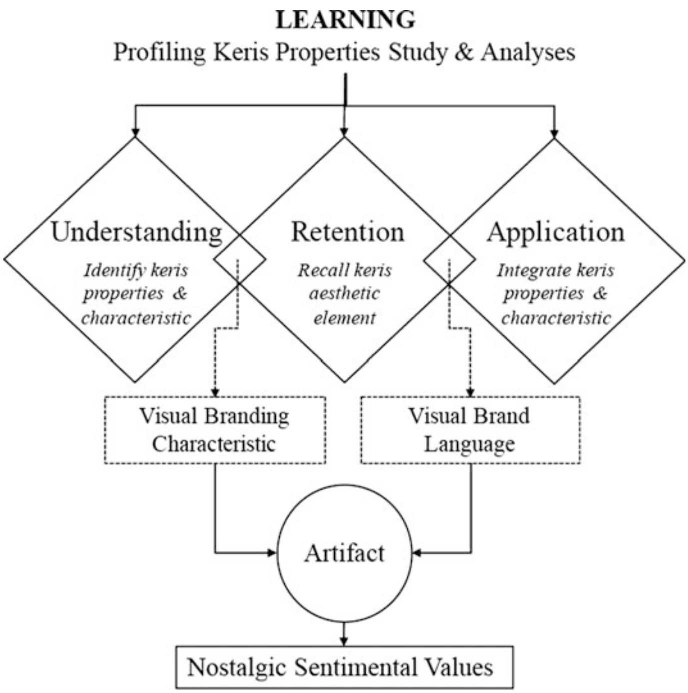

Fig. 21.5 Research conceptual framework of *Keris* profiling

will be focused on selective group [22] within product design industry as participation to determine the profiling of *keris* properties and the integration of the old and new idea towards their interpretation, identify [23, 24] and adaptation of the old and new ideas in relations to brand the characteristics of the product design.

The concept of profiling *keris* properties in relation to brand's characteristics of product design by measuring the abstract concept of branding characteristic identity. It defines the operationally measure and break it down to observable and measurable [25] characteristics to delineate the *keris* properties and characteristics of the brand characteristics identity concepts as in Fig. 21.5.

21.4 Conclusion and Future Works

This research would suggest a guideline and tool for future work of profiling Malaysian *Keris* DNA and properties in identifying the core values in brand recognition towards the Malaysian product design identity, in tandem to the Malay culture heritage to create and resonate. The Malay heritage NSV eventually would be able to educate and uplift our Malaysian culture and heritage values in brand identity perhaps to the global eyes and for acceptance.

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Figure 21.4 is a courtesy from Proton Design Group; therefore, I would wish to thank Proton Design Group for their support.

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Chapter 22
Defining the Concept of Visual Space in Mural Art Traditions of Rural Eastern Jharkhand

Pallavi Rani and D. Udaya Kumar

Abstract The rural communities of eastern Jharkhand paint their mud houses annually before the festivals. Various visual forms such as flowers, animals, birds and dancing human forms are painted on the external and internal wall of the mud houses. The placements of these visual forms on the wall vary from one region to another. To understand the concept of visual space in this art form among these communities, ethnographic research has been conducted in three administrative divisions (Santhal Pargana, North Chotanagpur and Kolhan) of eastern rural Jharkhand. Unstructured interview and documentation method were used to understand the concept of visual space in mural art tradition. Specifying the three mural-making mediums, three visual layouts are discussed in this study. Following these three layouts, the concept of physical and conceptual space of rural mural artist has been explained.

22.1 Introduction

In visual arts, mural is defined as two-dimensional artwork. It is executed in painted and applied form on the wall, floor, ceiling or other architectural element with a mutual relation to the architecture and environment [1]. Therefore, mural is a combination of art, architectural elements and space. Visual space is one of the elements of art that is defined and determined by shapes and forms. Literature shows that in two-dimensional arts like paintings (e.g. folk, miniature and scroll) and photography, visual space always gets the attention of the researchers [2, 3]. There is hardly any literature found pertaining to the study of visual space in traditional mural art. Concerning the art, architecture and visual space, the rural mural art forms of eastern Jharkhand are selected for the study. In this study, the

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Fig. 22.1 Painted mud houses of rural eastern Jharkhand

term “rural mural art form” is to mainly specify the artwork that is done by the local villagers on the mud wall, not by the professionals like, advertising company and marriage decorators. The rural communities (e.g. Santhal, Kurmi) of eastern Jharkhand paint their mud houses annually before the festivals. Various visual forms such as flowers, animals, birds and dancing human forms are painted on the external and internal wall of the mud houses (Fig. 22.1). This study aims to understand the idea of visual space in rural mural art tradition of eastern rural Jharkhand. The objectives of the study comprise the visual aspects (i.e. understanding of visual space arrangement) and cultural aspect (i.e. cultural significance) of rural mural art forms of eastern rural Jharkhand. The research questions have been formulated focusing on the concept of visual space among the rural artist of eastern Jharkhand.

22.2 Methodology

To understand the visual and cultural aspects of rural people, ethnographic research has been conducted in three administrative divisions such as Santhal Pargana, North Chotanagpur and Kolhan of eastern Jharkhand. Six districts of Santhal Pargana such as Dumka, Godda, Sahibganj, Pakur, Jamtara and Deoghar; two districts of North Chotanagpur Giridih and Dhanbad; and two districts of Kolhan division such as East Singhbhum and Saraikela-Kharsawan were selected randomly for the field study (Fig. 22.2). Different research methods, such as documentation and unstructured interviews, were adopted to collect the data. Notes on unstructured

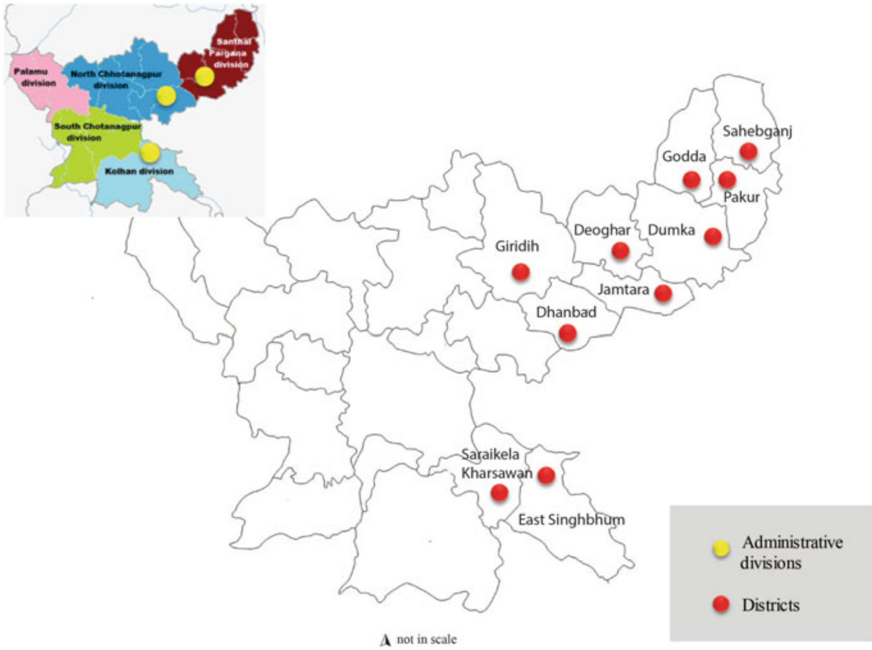

Fig. 22.2 Map of Jharkhand: location of selected administrative divisions and districts

interviews were made and noted with people's opinion, feeling and knowledge about the visual space. The collected data was analysed by finding the same pattern in documented artwork and notes.

22.3 Ethnographic Study

Ethnographic study has been conducted in three administrative divisions such as Santhal Pargana, North Chotanagpur and Kolhan of eastern Jharkhand and ten districts such as Dumka, Godda, Deoghar, Jamtara, Sahibganj, Pakur, East Singhbhum, Saraikela-Kharsawan, Giridih and Dhanbad (Fig. 22.2).

22.3.1 Documentation

Photography was used as key visual method to document the mural art forms. There are three mural techniques found. The layouts of all the three mural techniques are discussed here as mud mural layout, paint mural layout and rice paste mural layouts. These layouts are discussed below including the marking of wall division A, B and C or upper, middle and lower. The horizontal and vertical red dotted line shows the placement of creepers or plants, and cross dotted line shows the motifs.

Mud mural layout: In this, the mural is made on the wall by applying mud. Mud mural layouts are basically found in Santhal Pargana (Dumka, Godda, Deoghar, Pakur, Sahebganj, Jamtara) and North Chotanagpur (Dhanbad district) regions. The layout defines the most common visual form placement on the wall. In mud mural, the upper elevation of the wall comprises of horizontal border, creeper and motifs.[1] The border and creepers are mainly the repetition of geometrical and vegetative visual forms. Motifs are mainly painted above the horizontal border and creepers as a single and group. These motifs contain bird, animals and plant form. On the eye level, middle part of the wall contains creepers around the doorframe, group and single motif at the left and right side of doorframe. The creepers around the doorframe are depicted in mirror reflection with central motif[2] such as plant, pot or word. The visual layout of mud mural is shown below (Fig. 22.3).

Paint mural layout: The painted mud houses of Kolhan (East Singhbhum and Saraikela-Kharsawan) mainly contain horizontal bands and creepers or plants motifs around the doorframe in the middle-lower part of the wall. The painted bands are depicted with plain or decorative border in both sides (i.e. upper and lower). In the horizontal bands, repetition of geometrical shapes is painted on the middle of the band. The pattern of these shapes is designed in special organization which helps to visualize the background in shape or repetitions of shape. The organization of geometrical pattern makes a resemblance with figure–ground principles of Gestalt theory.[3] The upper part of the wall does not contain any visual forms and motif. The lower part of the wall (near the seating platform) is painted in flat black colour as horizontal border (Fig. 22.4). The single vertical line shows the placement of creepers or plants, double horizontal line shows the border/band or stripes, and crosses show the motif or repetition of motifs.

Rice paste mural layout: In North Chotanagpur (Giridih district), rice paste is used to draw the border and motif on the middle lower part of the outer walls of the house. During harvesting season, rural people draw borders on the wall to depict paddy fields. This paddy field is drawn in very simplified loop shape, and motifs are arranged within those borders. The visual forms are generally depicted in many layers. Middle lower part of the wall is the most preferable working area for the artist. In this mural medium, doorways are not painted with creepers, pot and central motif (Fig. 22.5).

[1]Motif is a decorative, narrative or iconographic image or design.

[2]The motif is presented in centre of any group motif like two birds with one pot. Here, pot is a central motif.

[3]Figure–ground organization is one of the principles of Gestalt psychology. In art, it is explained as perceptual grouping in which a figure is identified as a background and background identified as a figure through vision.

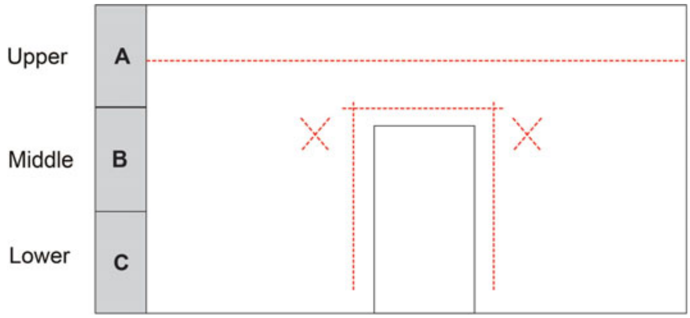

Fig. 22.3 Mud mural layout A, B and C is upper, middle and lower division of the wall

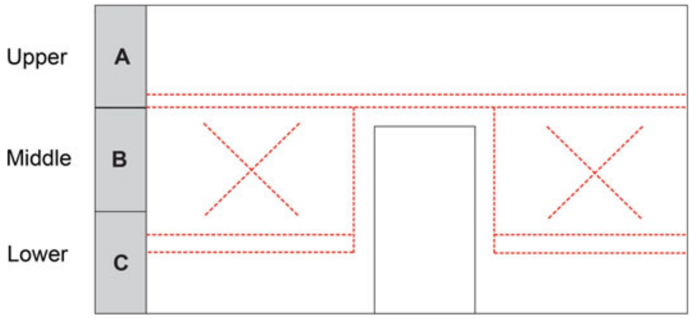

Fig. 22.4 Paint mural layout A, B and C is upper, middle and lower division of the wall

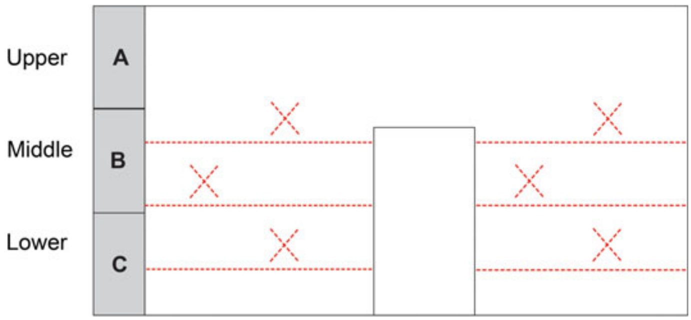

Fig. 22.5 Rice paste mural layout A, B and C is upper, middle and lower division of the wall

22.3.2 Unstructured Interviews

A total of 38 unstructured interviews were conducted in all the 10 selected districts. Age of the participants ranged from 15 to 50 years, both male and female. Sample size constrained for the study was 90, administrative division—30 and district—9.

The participants were farmers, labour, employ and housewives but are involved in mural making tradition of eastern rural Jharkhand. In the interview, questions regarding purpose behind making the murals, subject or theme of murals and reasons of placement of visual forms were clarified. The artist's opinion about visual space in mural and in general lifestyle was also discussed. By the conversation, it is understood that decoration, documentation, and prosperity are the main purposes of these living mural art traditions. In mud mural layout, birds, animals, flowers, creepers and plants are main visual motifs. In rice paste mural, agriculture motifs such as, paddy field, paddy and other corns are main visual motifs that are executed on the wall. In paint mural layout, geometrical shapes and horizontal bands are main visual forms.

22.4 Analysis

To analyse the layouts of three murals, participatory research followed in mural making events in villages of Dumka district (Santhal Pargana), Giridih district (North Chotanagpur) and East Singhbhum district (Kolhan). Detailed information about medium, execution techniques and painted visual form and shape was clarified by participating in mural making events. The upper part of the wall contains visual forms, and the middle and lower part of the wall contains that kind of visual forms which are interlinked in both part of the wall. The measurements conclude that in all three layouts rural artists are not following general divisions of wall like upper, middle and lower or A, B and C. It is found that there are only two divisions of wall that are done by the artist while making the murals. The updated layout has been shown below, in that the upper (A) and middle-lower (B-C) marks show the divisions of the wall (Fig. 22.6).

The contents of the unstructured interview were analysed finding the majority of similar words, sentences and similar meaning of words and sentences. There are some patterns from the statements that are discussed here. "We like to sit on the platform and in sitting position our back touch to the wall", "Our houses are like our

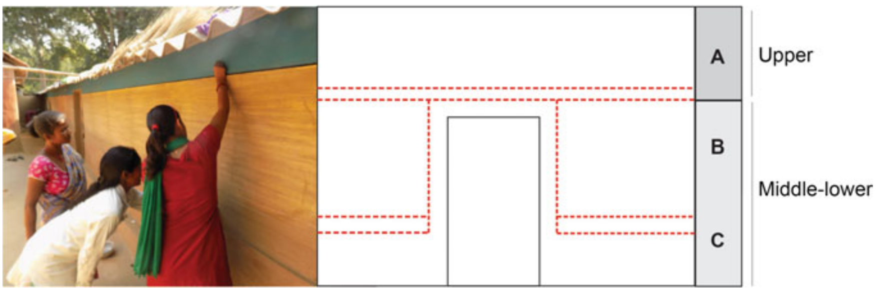

Fig. 22.6 Analysis of the layout

mother and the wall of the house is anchal", "Wall is like infinite space for us", and "We feel happy when anyone praise our mural while passing through the street". "In harvesting season, before going to the paddy field we draw paddy on the wall". These statements open various insights about visual aspects and cultural aspects. It can be said that the architectural elements (e.g. doorway, sitting platform, pillar and window) are essential part of the mural but there are some cultural phenomena which constrain them to picturing the wall not as a bounded space but beyond that.

22.5 Mural and Visual Space

In all three mural layouts, the front wall of the house (i.e. mural execution area) on which the subject of the artwork painted or executed is described as visual space among the rural artists. While designing the murals by the rural artists, the decision regarding visual space (e.g. space division, angle of visual form) effects two significant aspects of the space: one is physical space and another is conceptual space. Both concepts are discussed in the following paragraphs.

22.5.1 Physical Space

By the ethnography study, it is understood that the space which is the part of architectural elements and the space which is created by architectural elements deal with physical space among the villagers (Fig. 22.7). In figure "A" physical space is comprised of working space, empty space and depth of the architectural elements. While executing murals, depth of the architectural elements is either counted as empty space by the artist or as a figure on the wall which has shape and form. While executing the mural, depth of the architectural elements space always gets a special attention by the artist. As shown in the figure "A" following the shape of the architectural elements, visual forms are arranged.

Figure B and C mainly explains the house organization pattern in the villages. In selected villages, there is always a main street and small street between two houses. The entrance of some of the houses opens into the main street and some of them in the courtyard. There is generally a small street between the two houses. Generally, seating platforms are attached to the outer wall of the house and that marks the edge of the house. Houses mainly contain rooms, courtyard, veranda. In figure B and C, space which is created by architectural elements like main street, small street and courtyard creates physical space which is important to get the viewer's attention. In support of viewer's attention, it can be added that front wall of the house is the most decorated wall of the house and it contains entrance doorway and seating platform and there is always open space in front of the wall in the form of street and courtyard. In some villages, mural execution is not done on side and backyard wall because side wall is adjunct with small street or granary stores and these portions do

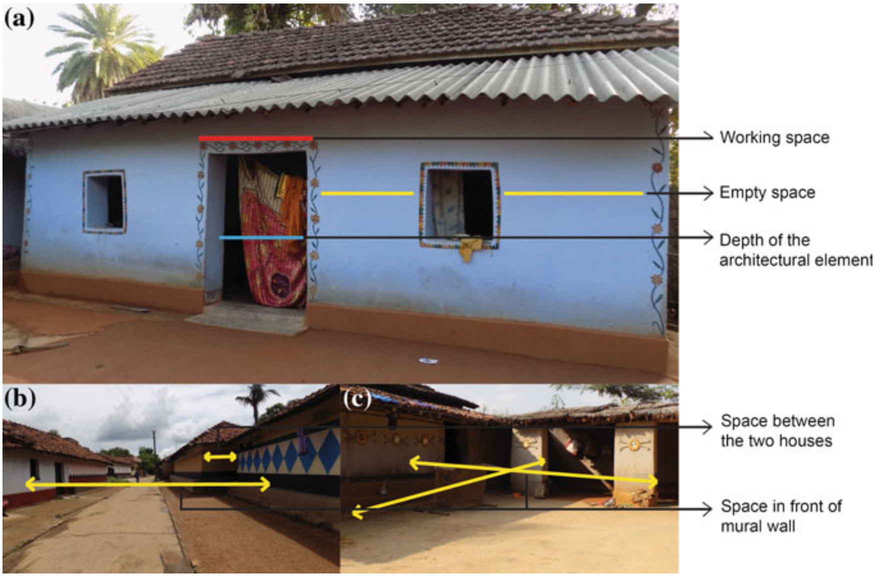

Fig. 22.7 Explaining physical space; **a** space within the architectural elements, **b** and **c** space created by architectural elements

not get viewer's attention. Consequently, the decorations on those walls are optional. In below paragraphs, all three layouts the physical space is discussed in detail.

Mud mural layout: Mud mural layout is mainly found in Santhal Pargana and in some villages of North Chotanagpur regions. In this region, most of the villages have courtyard style houses, and in this style houses, more than two entrances open in the courtyard facing to each other. On these entrance walls, murals are executed. The mural execution wall mainly contains doorway and sitting platform, and rarely window or ventilator is found on these walls. The height of the wall is generally 5–6 ft or more than an average human's height. The height of the wall motivates the artist to work on the eye level. As it is mentioned that the mural wall is the part of courtyard, and the courtyard is used for various household purpose such as for cooking, drying cloths or agricultural work. In these work, it is noticed that people use the seating platform for sitting purpose or keeping vessels. This habit indirectly guides the artist to make a proper distinction of foreground and background in mural. Consequently, creepers or plants and pot are drawn around the doorway. Rectangular shape of the doorway also directs the artist to mark the shape with the help of visual forms and repetition of visual forms. The space between the edge of the wall and doorways is used as working space and empty space. In this layout, empty space is found in vast area of the wall.

Paint mural layout: Paint mural layout basically found in Kolhan region. In this region, the entrance of the painted house mainly opens in the main street. In the main street, people dance, sing and perform many rituals. Their village governance council is also held in the main street. The seating platform is frequently used by the villagers for the sitting purpose. In the paint mural layout, the middle-lower portion of the wall carries most of the visual forms. In lower portion of the wall, the sitting platform attached to the wall is painted with plain bands. It is noticed that till the sitting height the bands are intentionally painted plain (i.e. without any motif or pattern). As the upper elevation of the wall generally used to dry clothes or to hang pitchers for pigeons, the upper portions of the wall are not painted with any visual forms.

Rice paste mural layout: Rice paste mural found in North Chotanagpur region. There are not any particular house patterns identified in this region. The entrance of the houses opens in main street, courtyard and sometimes in small street. In most of the house, sitting platform is attached with mural execution wall. Middle lower portion of the wall is used for the mural execution. Upper portion of the wall is used to keep some agricultural equipment and to dry cloths.

22.5.2 Conceptual Space

In this mural-making tradition, the involved communities are followers of various religions like Sarna, Hindu and Christian. The followers of Sarna religion are nature worshiper; for them, the cosmic space is the spirit world. Bir Bonga is the forest spirit. Jaher era is the spirit of the sacred grove, Dadi Bonga is the spring spirit, Marang Buru is the spirit who dwelt with the first Santhal, Pargana Bonga is the spirit of the region, Sima Bonga is the boundary spirit, and Manjhi Haram is the spirit of the founder of the village [4]. They worship animals such as bull, cow, cock, tree, farm barn and also other symbols of nature like Sun, Moon, stars, rivers and mountains. For them, the house is like "maa ka anchal",[4] and they have to decorate mother's clothes with various visual motifs. Cleaning houses with mud is equal to worshiping the mother earth. For the other communities, prosperity is interconnected with clean and decorated space. According to them, the divine god and goddess only pay their visit in decorated houses. Most of the communities decorate the main entrance of the houses to welcoming the guest who will come to pay their visit during festivals. Rycroft remarks that conceptually the entrance gate is decorated to welcoming the guest with flower garland [5]. The pot motif is represented as earth, which symbolizes the life in creepers. In layouts, the creepers and motif are arranged without the division of ground and the skyline by the villagers. It gives a perception of conceptual space among rural people. All three layouts discussed below defining the conceptual space.

[4]Anchal is the end/corner of the Saree (it is a traditional Indian dress worn by women), and in Hindi, it is known as Aanchal or Pallu. Aanchal is generally the most decorated part of the Saree. 'maa ka anchal' is a proverb used by the rural people for the decorated houses.

Mud mural layout: In mud mural layout, wall is seen as an infinite space or boundless space among the villagers of Santhal Pargana. They depict animals, birds, flower plants, creepers on their wall and show their gratitude to Mother Nature. Sometimes animals are placed in upper part of the wall and the birds in the middle. These arrangements clarify their angle of seeing this wall as earth in aerial view. The conceptual lay outing process makes the resemblance with the prehistoric art concept of visual form placement. The primitive concept of space suggests the visual world as a spatial extension of visual forms. Mathpal has mentioned in his cave art study that the prehistoric artist was not bound by conventional restrictions of space. There is no indication of ground line with the figure [6].

Paint mural layout: In paint mural layout, horizontal geometrical bands are never framed with vertical border. It defines that artist does not want to limit their earthen canvas within their own wall of the house; in fact, they want to create their conceptual space consistency beyond it. It also shows their social unity, in which they want to bind each other in one band symbolically.

Rice paste mural: In rice paste mural layout, agricultural motifs are painted in layers without perspective. In this mural art form, rather than considering the wall as a vertical canvas they consider it as an agricultural field. In support of that, they place their motifs in layers. They do not use any border to bind the wall, and they do not use any pot motif to represent the earth. Through this mural, they thank the motherland before working on field and paint their houses with agriculture-related motif. For them, it helps to increase their prosperity and wealth.

22.6 Discussion and Conclusion

This study opens new insights of visual space in rural mural art forms, it shows that the physical and conceptual space are essential aspects of space while designing the mural on the mud houses in eastern rural Jharkhand. At the physical level, the vertical earthen canvas can be visualized as two opposing groups: working space and empty space. The visual forms like border and motifs cover the working space of the layout, and the space around the visual forms is empty space of the layout. In mural layouts, the depth of the architectural elements is treated as figure and as empty space. At the conceptual level, the placement of visual forms does not follow a conventional understanding of space for instance. Here, the visual space defines the infinite space. In the mural layouts, rural people arrange visual forms in an infinite space at the conceptual level, and at the same time, they show their consciousness for doorframe, roof shed and seating platform for placing visual forms as physical level. This compositional aspect gives valuable clues of equal importance of conceptual and physical space in rural mural art forms. It can be concluded that, in these mural art forms, the physical concept of space defines the visual space beyond the frame, and at the same level, conceptual space defines it within the frame. It can also mention that the shape of the wall, order of houses, daily lifestyle, nature attachment and superstitions encourage the villagers to organize visual elements in a certain layout. The physical and conceptual aspects of rural community and its representation in murals stand in their own signature style among others art forms.

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Chapter 23
Appreciation of Art with Vision and Color

Nilima Regina Topno, Shatarupa Thakurta Roy, Noopur Anand and Vikas Kumar

Abstract Art is the creation of human skill and imagination in a visual form. Hence, it becomes imperative to study vision and color for the greater appreciation of art (Feinsher in what is color? Color how to use color in art and design. Laurence King Publishing Ltd., London, pp. 2–3, 2006, [1]). Understanding the concepts of luminescence, color, contrast, acuity, surrounding, equiluminescent color, shading, resolution, and perspective can help appreciate better the masterpieces of artists. It is an attempt to not only understand art but also to understand how human mind works and conjures images which lead to a deeper understanding (Feinsher in what is color? Color how to use color in art and design. Laurence King Publishing Ltd., London, pp. 2–3, 2006, [1]). It is an attempt to deepen the relationship between art and science. There are no fixed criteria for judging masterpieces, but it is the ability to assess skill, craftsmanship, and workmanship unique to the master. In understanding concepts of vision and color, the scientific aspects of art are clearly defined; hence, art no longer remains art, but a different view of it emerges compelling us to appreciate the masterpieces and the artistic expressions.

23.1 Introduction

Art has been a form of expression of the human mind. In art, the artist expresses his thoughts, fears, desires, and happiness. He gives concrete shape to abstract as Tagore said: "In Art man reveals himself." This is what translates on to the canvas, and the expressions of the artist are captured for the viewer to experience. It is, therefore, important to have a clear understanding of these techniques to understand

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how a viewer experiences art in his or her mind. Hence for better appreciation of art, one needs to understand the principles as well as the choices of expressions of the elements of luminescence, color, contrast, acuity, surrounding, and equiluminescent colors are the tools the artist uses to express himself/herself [2].

23.2 Luminescence

It is also referred to as value, which is determined by the eyes and light contact. There is a part of the visual system which responds to the difference in luminescence and is insensitive to color differences [3]. In the visible light spectrum, we see that the blue appears dimmer than the yellow part. Thus, the nature of the color determines the luminosity present. It is also said that by changing the light source, one can change the perception of color as the human photoreceptor is more effective in the presence of more light. The rods in our eyes are responsible for luminescence but are so only under the conditions of dim light and are not very useful in full daylight. These signals are further carried on by the cones in the eyes [3] (Fig. 23.1).

In the above painting, we can see how the luminescence of the yellow faces and hands is overpowering the entire painting and the blue and the darker shades are having a tone down effect.

23.3 Color

It plays one of the most important roles in vision and is usually perceived by the cones in the eyes. The photoreceptor responds to colors in the different wavelength, namely the short, medium, and the long. The visible spectrum has the wavelength from 380 to 750 nm [4]. There are cones which are sensitive to blue light to green

Fig. 23.1 Praying Maidens by Tom Vattakuzhy

light and to the red light. Cones detect the primary colors [4]. Color blinds are those people who have the defect in these cone regions; hence, they see images with lesser colors [5].

This brings us to question whether every person sees the color with the same intensity is the color. As different people experience different taste for the same thing so also different people experience differently the same color, i.e., a particular red color look red for Mr. A with the same as the same intensity for Mr. B. People experience color differently and that is why their reactions to artworks are also different.

23.4 Contrast

The contrast in colors is vital to of visual patterning. Contrast is a means of expressing a contour. The firing of neurons in the eyes or their non-firing is responsible for the creation of lines, contours, and shades. The recordings of which occur in the retinal ganglion cells. It is also called the center surround or the surround suppression in the cells. If there is a drawing with white on one side and dark on the other, the center-surround cells on the white side will be activated while that on the other side will be dormant. It is only where there is a contrast or misbalance that the cells are activated. Our eyes are more sensitive to abrupt changes than they are to gradual changes. Hence, it is difficult for us to detect a gradual shade variation [6]. The adaptation of eyes to the black print in daylight and to the white in dim light in a newspaper is evidence enough of our eyes being sensitive to different contrasts depending on the type of lighting. Artist has always taken advantage of this selective sensitivity to detection of edges and contrasts. The

Fig. 23.2 The Pink House by Tom Vattakuzhy from Kerala

gradual change of luminance in background painting had led to shifting of focus to the perceived luminescence in the foreground. So sensitive are our eyes to lines that even babies start using lines from a very tender age [6] (Fig. 23.2).

In the above painting, we can see how the luminescence of the colors has been enhanced, and even though in a real photograph, this luminescence will not be caught somewhere in the back of the mind. We are aware of what the human eye has caught in the painting. So important is the surround color effect. The colors in the center are same but have a different effect when contrasted by different colors.

23.5 Surround Effects of Color

The fact is that there are three basic receptor cones of colors. These are the basis for the primary colors, namely red, blue, and green primary colors, and with their colors, the other colors can be developed and perceived which can be in millions and is one of the rarest miracles of nature. But it is not actually difficult to perceive as there are pixels of high definition color in displays of 7680 × 4320 px displaying more than 17 million colors [7]. What is even interesting is that our eyes respond to colors of the background of an object. The center-surround effects assist in a greatly in edge detection. The retinal ganglion cells, thalamic cells, and the visual cortical cells are responsible for this detection. Surround antagonism in color is a feature when the same object can look different with different background of color. The theory of color opponency and after imaging is that after staring at a red color for a long time, one sees the after an image of cyan color, and if you stare at a yellow image for a long time, you see a blue after image. Color and luminescence from any point in a visual painting have a very different response when there is a surrounding color to the visual space [3] (Fig. 23.3).

The green hue of the apple is very different when the background color changes. That is because the cells detecting the color purple are fatigued and starts having an influence on the green apple color [3]. Hence, it is not important to have color in the entire expanse of the painting. The fact is that our visual system can give different responses to different color wavelengths. The eyes are also sensitive to the type of

Fig. 23.3 **a–c** The green apple with different colored background. Artist Sagar Srivastava from NIFT

Fig. 23.4 The last supper by Tom Vattakuzhy from Kerala

light falling on the surface, which is why pictures with filter colors look different and can easily be experienced in a mobile application of changing filter colors for a photograph. This feature has been extensively used in Tom Vattakuzhy's painting, where the prominent source of illumination seen is only two prominent sources, but the reflections of a light source change the illumination of the faces and bodies in the picture also changes the spatial look of the surrounding and the spatial organization of the painting due to the color of the light source (Fig. 23.4).

23.6 Acuity and Resolution

The human eye has a very low visual resolution in areas where eyes are not focused [8]. We only see what we want to see. Many artists have used this feature to their advantage. This is because the fovea region of an eye has the highest acuity. Even though we have blurred image in the periphery, we are still able to detect the forms. Many painting and camera pictures are not actually what we see in reality but are made of minutest details which we miss at a glance. Impressionist artists actually painted memories capturing the moment (Fig. 23.5).

In the above artwork, we see a clearer perspective of how the eye is trained to see. At one time, it can focus only on the foreground or at any point of focus. Most artists recreate a memory of the complete imagery, but there are some who have used this to direct the eyes of the observer to areas of their composition which they have given importance to.

Fig. 23.5 The World Cup Artist Amit Kumar from NIFT

23.7 Color

The resolution under which our eyes work for color is actually of low resolution such that we see in blurred lines, and most painters have understood this feature. Hence, it is actually not important to work within high contrasting lines [8] (Fig. 23.6).

In the above painting, we see how the edges are blurring still the painting makes sense to the viewer. This is also known as optical mixing where the colors seem to spread inside the edge of the boundaries giving the painting a tint of the color. The rendering technique of the eyes makes the eyes look alive.

Fig. 23.6 The eyes of a dog. Artist Shubhangi from NIFT

Fig. 23.7 Collage of feet. Artist Riya Shah from NIFT

23.8 Pointillism

In color printing, very tiny dots are used for printing color and printed alphabets. The same concept is used in pointillism where the individual dots are small, but the mixing of color gives the image a third hue. This is because the visual perceptive cells are unable to identify the individual dots; hence, the colors merge together. The mixing of colors is seen in magazine colors, where mixing of colors gives vibrant colors which would not have been possible in the additive mixing of colors. Hence, the optical mixing of colors is actually very different from the physical mixing of colors. The same concept is also used in computer monitors and mobile phones, where the small images at high resolution are integrated into one image. Pointillism concept is one of the most important concepts discovered by artists and now has been adopted into displays [9] (Fig. 23.7).

Colors can also be blended into each other. When the luminescence quality of a color is added into one another color of the same luminescence, a fascinating blend is achieved which seem to flow into the space of the other. The border in such a case becomes illusionary.

23.9 Equiluminescent Colors and the Illusion of Motion

The concept of luminescence independent of color is a much-debated topic. Much used by many painters give the perception of movement in a painting [10]. The reason as to why this happens is because the visual system can identify what the object is but cannot place where the object is because there is not enough contrast in the luminescence. Hence, there is an ambiguity in distinguishing the colors from borders. The glow in the candles in Tom Vattakuzhy's painting is a reflection of this concept, where the glow seems to be spreading outwards (Fig. 23.8).

Fig. 23.8 Candles by Tom Vattakuzhy from Kerala

23.10 Shading

When we observe the world around us, we see it in a three-dimensional form. The visual system computes both dimensions of distance and depth. Artists render the three-dimensional world on to a two-dimensional canvas which has the aspects of three dimensionalities. How are they able to achieve this feat? They use concepts of occlusion, haze, shading, and perspective to provide for depth on a flat background. The luminescence of an object can be reduced by shading; hence, an artist should be able to think without color interfering [3]. The background shading plays an important role in giving the object a three-dimensional feel. In the painting of Tom Vattakuzhy below Fig. 23.9, we see how luminescence has been used to highlight the stones giving a three dimension to the painting giving it a sense of depth. As

Fig. 23.9 Pebbles by the river by Tom Vattakuzhy from Kerala

Picasso said, "Reality can be found in luminescence alone." The concept of perspective is because light travels in straight lines and the angles with which light enters the retina from the perspective angle [11]. The brush techniques are also important in creating three dimensionalities. The use of thicker paint and brush strokes can also give a feeling of three dimensionalities and with same with repetitive patterns, i.e., repeat pattern of stones give the feeling of illusionary depth [12].

23.11 Perspective

Perspective has been used to depict depth even before the period of Renaissance. Perspective explains the principle that light travels in straight lines. Hence, there is a geometrical explanation to the concept of perspective. Most of us cannot consciously see receding lines as being convergent. It is even difficult for the artist to visualize a 3D image on a flat two-dimensional paper Fig. 23.9 Pebbles by the river are a classic example of perspective painting.

23.12 Conclusion

In understanding the various techniques of painting which artist have mastered through sheer practice and patience, we understand how human mind interprets these concepts through the vision which is the most powerful of the five senses. Luminescence is used to give a perception of depth and to highlight certain portions of the painting. Different colors have different effects on painting and on the observer. Equiluminescent color allows motion in paintings; acuity and resolution play an important role in portraying reality in painting. The concept pointillism in magazines and digital displays is now of common use. Shading assists in giving the illusion of depth in flat surfaces. Perspective also adds depth to a painting. The artists follow the basic principles of nature and vision to give concrete shape to their thoughts and ideas. Only when we understand the way vision interprets details, we can truly appreciate art as the two have an extremely symbiotic relationship.

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Chapter 24
Design and Development of a New Instrument for Measuring Aesthetic Sensitivity

Sunny Bairisal and Jyoti Kumar

Abstract Aesthetic sensitivity has been reported as a prerequisite of aesthetic experience. Designers need to understand differences in appreciation of aesthetic objects by intended user group of their designed artifacts. This paper proposes a new instrument to measure aesthetic sensitivity. The proposed instrument consists of 43 items; each item further consists of five visual compositions. A total of 125 subjects were chosen from different age groups and educational backgrounds. Subjects were asked to rank order the compositions based on their feeling of pleasure while looking at them. The internal reliability of items was found to be statistically significant.

24.1 Introduction

The designer is a planner with an aesthetic sense [1]. Aesthetic sense is important to all of us [2, 3]. Aesthetic designs facilitate aesthetic experience [4] and help in making aesthetic preference [5]. Aesthetic experience has been regarded as one of the highest experiences [6] but to have an aesthetic experience, the observer needs to have a suitable aesthetic sensitivity [4]. The aesthetic experience needs to be sensitive enough to identify "the beautiful aspect of beautiful object" [7]. Aesthetic sensitivity refers to the ability to perform a set of "perceptual analysis" of the stimulus [7, 8]. Aesthetic sense is a sense of what is fitting, harmonious or beautifully in object [5]. It deals with special mental faculty possessed by the few people. Aesthetic sensitive individuals have sophisticated or superior preference than others, not everyone possessed aesthetic sense [2, 5, 9, 6].

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This paper has argued for a need of an instrument for measuring aesthetics. The focus of the present work is to develop a new aesthetic sensitivity measurement instrument.

24.1.1 Background

Literature review suggests that there is much diversity in methodology and approaches used in experimental aesthetics for measuring aesthetic sensitivity [2]. It has been found that different tests used different stimulus materials for measuring aesthetic sensitivity [10]. As the theoretical premise for aesthetic experience is that "an observer needs to have an aesthetic sensitivity for an aesthetic object to be able to generate an aesthetic experience", thus one way to measure the aesthetic sensitivity is that ability of differentiation between aesthetic and non-aesthetic stimuli by observers be used. Several attempts using the above method have been reported in the literature. In one such test, artist drawn pairs of harmonious and non-harmonious abstract images in black and white were used in Visual Aesthetic Sensitivity Test (VAST) to gather "right" and "wrong" selections from participants to assess their aesthetic sensitivity [3]. Similarly, Child's test (1962), Barron and Welsh's Figure preference test (1952), Meier test I (1941), Meier test II (1963), and AJT (Bamossy 1985) used "work of art" as stimulus material. All tests asked participants to choose one between the two given design, whereas Grave's Test (1948) and Thorndike's Test (1916) used "Formal design" elements such as Rectangles, Crosses, and Geometrical designs as stimulus materials and asked participants to "rank order" based on their likings for stimuli. Moreover, Child (1962) suggested that in order to design a measuring instrument for measuring aesthetic sensitivity, it is necessary to apply "method to stimuli design" [10].

This paper proposes a "method of designing stimuli" for measuring aesthetic responses. The method is based on the framework of product experience [11], Kant's (1790) philosophy of aesthetic judgment and Indian aesthetic philosophy given by Abhinavagupta (c. 950–1016 A.D) [6].

24.2 Methodology

a. **Method of stimuli design**

An aesthetic experience is a part of product experience that includes the entire set of experiences such as emotional experience and meaningful experience. The experience deals with the degree to which all our senses are gratified or pleasurable to senses is known as aesthetic experience. The rest of the experience deals with the faculties of human minds, i.e., cognition and emotions. They should be conceptually separated either while designing for user experience or while making an aesthetic design decision [12, 11].

Aesthetic responses are different from meaningful experience and emotional experience, in Kant's word "disinterested" [4], i.e., desire free from our concerns and goals. Aesthetic judgment is not based on any ideas or concepts. Kant (1790) said beautiful is "Cognized without a concept as the object of necessary satisfaction" [13]. Moreover, aesthetics is a matter of experience and an aesthetic sensitive person can have direct aesthetic experience even through implicit determinants, they don't need its dramatic representation (Abhinavagupta, c 950–1016 AD) [6]. This paper posits that to measure aesthetic sensitivity, stimulus should contain only aesthetic component and be free from emotional and semantic components such as colors, personal desires, brand names, brand identity, social, cultural-moral values, and symbols in order to capture only aesthetic sensitivity. In other words, aesthetic design stimuli should contain only aesthetic components such as aesthetic design principle and free from emotional components, semantic interpretation, and symbolic association.

Product experience = Aesthetic experience + Emotional experience + Semantic Experience [11].

Method of stimuli design → Aesthetic experience (experience of sense gratification) ~ Product experience—Emotional experience (deals with the faculty of the human mind)—Semantic experience (deals with the faculty of the human mind).

As an example of three different levels of experience during product experience, let us say a word MAN is written like this [], which consist of all three levels of experience that is discussed above. Emotional experience, i.e., human being's, meaningful experience of hard, sharp, pointed edge and aesthetic experience of order, parallelism, etc. In Abhinavagupta's (c 950–1016 A.D) words, it is "dramatic representation" of emotional experiences (*Bhava*) with respect to human beings as well as the meaning of hard, sharp and pointed edge (*Vibhava*). Moreover, aesthetic components give the pleasurable feeling of ordered, parallel arrangement of lines. If we separate the emotional component "MAN" from the same word will look like this []. This form of a letter has no emotion (*Bhava*) of a human being attached to it but the only meaning of hardness and aesthetic experience of ordered and balanced lines. Again, by careful removal of a meaningful component of "hardness" from the letterform, we will get a pure aesthetic component that is responsible for its beautiful appearance. The letter form will look like []. This letter form contains an only aesthetic component of parallel order and balance. Authors are arguing that stimuli like [] can serve our purpose of measuring aesthetic sensitivity because it has an only aesthetic component in it and free from emotional and meaningful components, i.e., "disinterested" or "non-dramatic representation" (Table 24.1). For example:

According to the definition given by highly aesthetic sensitive person are those who give above average [14], and higher weight [1] to beautiful stimuli such as order and symmetry though basic perceptual analysis [8], they are good at perceiving subtle difference [5] and are able to discriminate fine demarcations which

Table 24.1 Representation of all three levels of experiences w.r.t word "MAN"

Stimulus	Levels of experience
	Emotional experience (human being), experience of meanings, and aesthetic experience
	Experience of meaning (hard, sharp, and rough) and aesthetic experience
	Only aesthetic experience (order, parallelism, consistency), non-dramatic representation

remains unnoticed to the untrained eye [4]. So, by making changes in variation through systematic manipulation of aesthetic stimuli, the author created four different design dimensions for aesthetic stimuli, like (Fig. 24.1):

This paper is arguing that the above method of stimuli design can facilitate measurement of aesthetic sensitivity and instrument design. A tool to measure aesthetic sensitivity was constructed by removing semantic and emotional experience from brand logos, pictures, etc. to get a purely aesthetic judgment on an aesthetic component. The designed instrument is generated by systematic manipulation of the aesthetic component, i.e., design principles of stimuli. For the construction of stimuli, author used geometric shapes as they are easy to manipulate due to its objective nature, therefore, a consensus of art experts is not required. Earlier Fechner (1876) identified the relation between design dimension and aesthetic appreciation through systematic manipulation of design dimensions of rectangles [15]. In this study, author has created 43 stimulus materials for measuring aesthetic sensitivity by using and manipulating design principles such as golden ratio, symmetry, balance, and rule of third (Fig. 24.2).

b. **43 stimulus material created using above stated method of stimuli design:**

In order to score high, participants had to "rank order" the compositions on the basis of order, balance, symmetry, and golden ratio. Those who can perceive the subtle difference between "correct design dimension of design principle" and "manipulated dimension of design principles" and are able to give more weightage to the composition in either golden ratio, balance, or rule of third is considered as a highly **aesthetic sensitive person**.

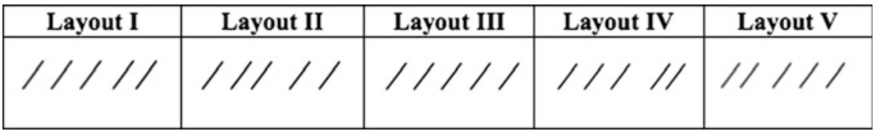


Fig. 24.1 Example of stimulus created for measuring aesthetic sensitivity by removal of an emotional and meaningful component from the word "MAN"

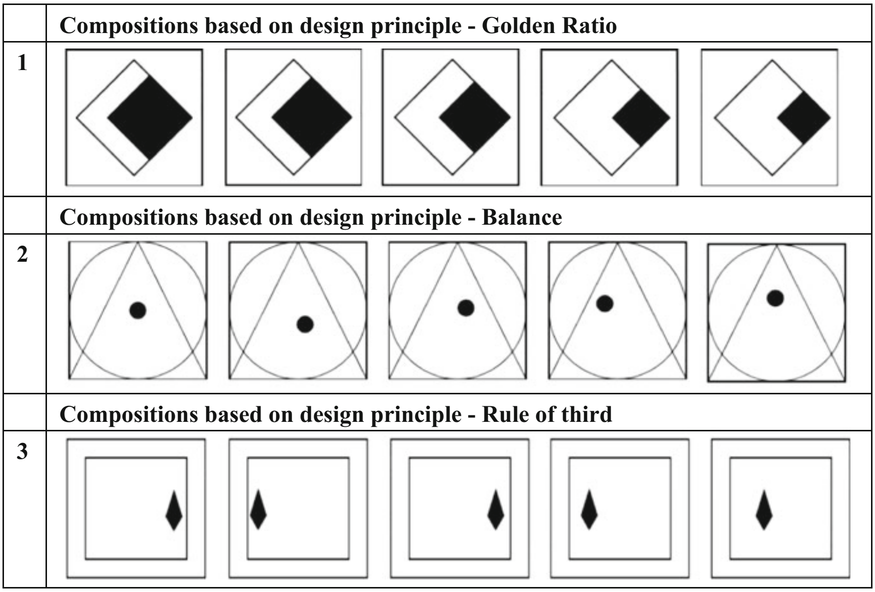


Fig. 24.2 Example of stimulus created for the development of an instrument for measuring aesthetic sensitivity

24.3 Experiment Conducted

An experiment conducted is based on the hypothesis that “Are there really some people who are sensitive to beauty”. A total of 125 Participants were asked to “rank order” the compositions from 1 (most pleasing), 2 (pleasing), 3 (neutral), 4 (displeasing) to 5 (most displeasing) based on the feeling of pleasure while looking at them. Experiments were conducted individually to capture personal, individual decision and to avoid heteronomy. Participants were encouraged to give their reaction under 20 s because aesthetic responses are an immediate response to the artifact, they are quick, faster, and spontaneous [9, 10].

24.4 Data Analysis

Two types of aesthetic sensitivity measures have been reported in the literature. Experts have been used as “the yardstick” in some studies such as Meier Test I (1940) & II (1967), VAST (H. J. Eysenck [3]), AJT and an Object Preference Test (Macklin A.D., 1991), because all these tests used artwork as a stimulus material. While in others, “aesthetic principles” have been used as “ideal” such as in Thorndike [11], Barron and Welsh’s Figure preference test (1952). Aesthetic principles are objectively determinable and serve as a heuristic for aesthetic judgment, thus do not require the involvement of art experts.

In order to score high on test, participant's ranking must be in consensus with either correct order or near to the correct order. The correct order of the design compositions is based on the design dimension of design principles and manipulated design dimension of design principle. The guidelines to assign weight to the compositions are given as follows:

1. The weight of the design dimension of the design principle > weight of the design dimension of the manipulated design principle.
2. The weight of the design dimension of the golden ratio design principle > weight of the design dimension of symmetry design principle > weight of the design dimension near to the golden ratio > weight of the design dimension far from the golden ratio design principle > weight of the design dimension very far from the golden ratio design principle.

According to Titchener (1899) and Rudolf Arnheim (1954/1974), the highest level of aesthetic development, the symmetrical division is repeated by what it is known as Golden section. Fechner (1876) found the golden ratio as the first preference for most of the people. Similarly, a ratio close to the golden ratio is also preferred over other ratios. Alongside with the golden ratio, next preferred ratio was found to be Square [15]. Therefore, the weight given to the golden ratio, symmetry (equal division), a ratio close to the golden ratio, a ratio far from golden ratio, and ratio very far from golden ratio is 30, 25, 20, 15, and 10, respectively, as shown in Table 24.2.

Again "weight to participant's rank" were assigned as Rank 1 = 1, Rank 2 = 0.8, Rank 3 = 0.6, Rank 4 = 0.4, and Rank 5 = 0.2 as shown below.

Table 24.2 Example of weight distribution to the compositions

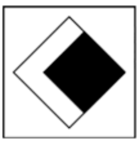
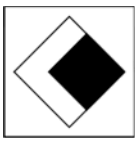
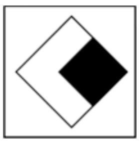
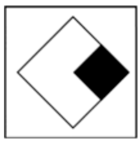
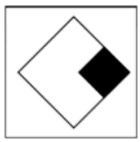
	I	II	III	IV	V
Stimulus 1					
Ratio	1.35	1.42	1.61	Near to Equal div.	Equal div.
	Manipulated version		Golden ratio	Manipulated version	
Weight	10	15	30	20	25

Table 24.3 Representation of averagely weighted analysis of participants 1 and 2 for stimuli 1

Weight to correct order	10	15	30	20	25	Average weight score
Ideal rank for stimuli 1	5	4	1	3	2	
Weight given to rank	0.2	0.4	1	0.6	0.8	
Ideal score	**$(0.2 \times 10) + (0.4 \times 15) + (1 \times 30) + (0.6 \times 20) + (0.8 \times 25) = 70$**					
Participant 1 (weight to rank)	0.4	1	0.6	0.8	0.2	58
Participant 2 (weight to rank)	0.6	0.4	1	0.8	0.2	63

Participant 1 ranking	4	1	3	2	5
Weight assigned to ranking	0.4	1	0.6	0.8	0.2
Participant 2 ranking	3	4	1	2	5
Weight assigned to rank	0.6	0.4	1	0.8	0.2

The average weighted analysis was performed in order to calculate an individual's score for aesthetic sensitivity (Table 24.3).

24.5 Result

Since aesthetic preferences in product design obey certain rules or principles. These aesthetic principles are rooted in human nature for helping us in adaptation. The rationale behind these principles is an evolutionary one [4]. Thus, we can conclude that having an aesthetic sense to identify some universal rule is extremely useful for designers. This paper facilitates instrument design for measuring aesthetic sensitivity. Therefore, experiment performed with 125 students consisting of 34 design students, 29 B. Tech fresher's (12th Std. passed out) students, 10 Art students, 16 Engineering students final year batch, 19 master's engineering students (M. Tech), and 17 Hostel mess workers. Among them, 3 B. Tech fresher's, 1 B. Tech final year student, 1 M. Tech student, and 2 design students achieved the highest score on a measurement of aesthetic sensitivity. Authors found normal distribution curve of the average weighted score as a measurement of aesthetic sensitivity (Fig. 24.3). Rank ordering represents the order of the stimuli according to their aesthetic value. The variation among person provides a measurement of aesthetic sensitivity [10]. As a result, it has been found a significant difference between aesthetic sensitivity of workers (age group, 30–40 years old, low educational, and socio-economic background) and B. Tech 1 year's students (age group, 18–20 years, high educational, and socio-economic background). Therefore, we can conclude that aesthetic sensitivity is independent of the education dimension. However, age and socio-economic background has an influence on it. Through this knowledge, designer can identify jury of "aesthetic sensitive individuals" within the institute or organization. The jury of these individuals can help designers by giving their valuable feedback on aesthetic product design decision-making process. Since there

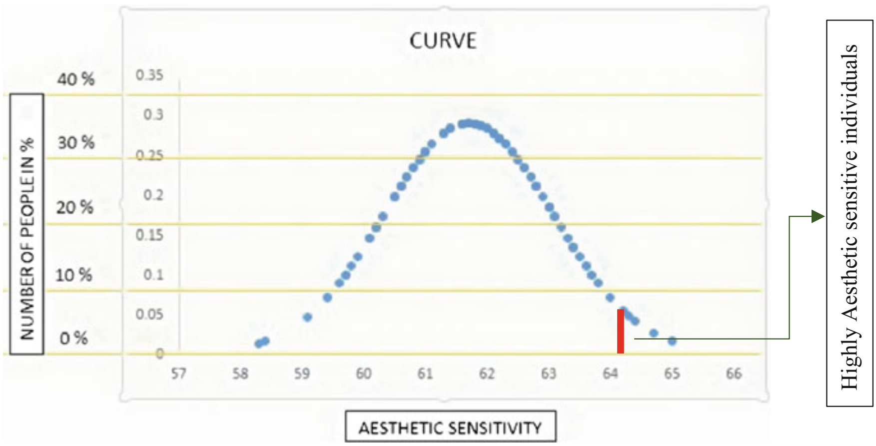


Fig. 24.3 Normal distribution of 125 participants and their measured score of aesthetic sensitivity

Table 24.4 An average weighted score of all 125 participants across the scale (43 stimuli)

Subjects	Score	Subjects	Score	Subjects	Score	Subjects	Score
Artist	**61.95**	Design.	**61.28**	12th Std.	65.00	M. Tech	**60.86**
Artist	**62.07**	Design.	**62.14**	12th Std.	**62.91**	M. Tech	58.33
Artist	**62.19**	Design.	**64.00**	12th Std.	**61.91**	M. Tech	**60.21**
Artist	**61.93**	Design.	**63.4**	12th Std.	**62.21**	M. Tech	**62.00**
Artist	**60.95**	Design.	**61.8**	12th Std.	**63.09**	M. Tech	**62.81**
Artist	**61.44**	Design.	**63.3**	12th Std.	**62.51**	M. Tech	**60.51**
Artist	**62.95**	Design.	**63**	12th Std.	**63.51**	M. Tech	**62.28**
Artist	**60.98**	Design.	**61**	12th Std.	**63.56**	M. Tech	**65.05**
Artist	**60.26**	Design.	**61.76**	12th Std.	**62.16**	M. Tech	**61.95**
Artist	**60.80**	Design.	**60.06**	12th Std.	**61.56**	M. Tech	**61.86**
Design.	**61.58**	Design.	**62.16**	12th Std.	**61.65**	M. Tech	**61.91**
Design.	**62.23**	Design.	**59.93**	12th Std.	**64.40**	M. Tech	**60.72**
Design.	**63.44**	B. Tech	**63.07**	12th Std.	**63.77**	M. Tech	**60.81**
Design.	**60.6**	B. Tech	**62.65**	12th Std.	**61.37**	M. Tech	**60.35**
Design.	**60.9**	B. Tech	**62.21**	12th Std.	**60.56**	Worker	**60.83**
Design.	**61**	B. Tech	**62.67**	12th Std.	**62.16**	Worker	**63.72**
Design.	**61.7**	B. Tech	**64.65**	12th Std.	**62.42**	Worker	**61.37**
Design.	**61.05**	B. Tech	**63.37**	12th Std.	**62.81**	Worker	**60.5**
Design.	**61.35**	B. Tech	**62.47**	12th Std.	**63.00**	Worker	**58.44**
Design.	**59.65**	B. Tech	**60.87**	12th Std.	**63.07**	Worker	**59.09**
Design.	**62.42**	B. Tech	**61.63**	12th Std.	**61.26**	Worker	**60.6**
Design.	**64.16**	B. Tech	**59.42**	12th Std.	**64.33**	Worker	**60.2**
Design.	**63.4**	B. Tech	**61.63**	12th Std.	**61.6**	Worker	**60.6**

(continued)

Table 24.4 (continued)

Subjects	Score	Subjects	Score	Subjects	Score	Subjects	Score
Design.	**60.86**	B. Tech	**63.21**	12th Std.	**59.77**	Worker	**60.1**
Design.	**60.58**	B. Tech	**63.40**	12th Std.	**61.88**	Worker	**59.65**
Design.	**60.26**	B. Tech	**60.16**	12th Std.	**60.70**	Worker	**61.26**
Design.	**62.09**	B. Tech	**60.19**	M. Tech	**61.84**	Worker	**61.09**
Design.	**60.67**	B. Tech	**63.56**	M. Tech	**62.56**	Worker	**60.21**
Design.	**62.79**	12th Std.	**62.77**	M. Tech	**59.58**	Worker	**60.07**
Design.	**63.65**	12th Std.	**62.33**	M. Tech	**60.5**	Worker	**62.6**
Design.	**61.77**	12th Std.	**62.63**	M. Tech	**59.42**	Worker	**60.5**
Design.	**62.95**						

are no "aesthetic testing labs" available for analysis of aesthetic, this type of study can also facilitate designers to know whether the target group prefers aesthetic over functionality or not, by comparing two groups' mean score. Further, the designer can think over design and investment on design based on the target group's aesthetic sensitivity (Table 24.4).

The aesthetic sensitivity of 125 participants was evaluated using a presently designed instrument of reliability (α) which came out to be 0.7. It has been found that only 6% of participants are highly aesthetic-sensitive individuals or have the ability to find beautiful aspects, and their score is very close to external value, i.e., 70 (Ideal Value) as assigned by the author, to the composition based on design principle. Test–Retest validity test was also conducted with some 20 participants after 3 months of a gap and found no significant differences in their responses.

24.6 Limitations and Future Scope

Some aesthetic design principles are general, uniform in human nature [5], guide our aesthetic preference [4], and responsible for aesthetic designs [12]. While an aesthetic artifact or an artist's aesthetic sensitivity cannot be limited to an evaluation by theoretical principles. But there is a practical need in design disciplines to do some assessment, however, limiting. This paper has tried to develop a tool for assessment which may require further research for development into a complete tool for all situations. According to Fechner (1876), the knowledge of response to simple 2D pattern has the potency to understand behavioral responses toward 3D forms [16]. This viewpoint has been criticized as well as accepted by several authors. The present designed instrument is limited to the application of only three design principles. There is a possibility of various instruments with application of various other design principles and well as without design principles. For example, with complex curves, artworks, and 3D forms.

24.7 Conclusion

Method to stimuli design is easy "to apply" in and "to administer" the aesthetic sensitivity test. The evidence for reliability and validity suggests that the present design instrument is sensitive enough to measure aesthetic sensitivity by discriminating aesthetic sensitive individuals among the group.

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Chapter 25
Color in Traditional Indian Architecture—An Inquiry into the Color Family of Reds

Saili Sonar

Abstract Color is an important and fundamental part of interior architecture. It is present on every element in the space around us with its unique manifestation. India is a country with a rich history of architecture. Red is the color family of natural materials like earth (or mud), terracotta (or clay), stones and brick, which is extensively used in built forms since antiquity. These are the most important building materials used in today's context as well. The red family also holds equal importance as an applied color to traditional Indian built forms. This particular research aims to identify various kinds of reds used in the traditional architecture of India with respect to the inherent colors (of materials itself) as well as the applied colors (as surface applications) seen on the main building elements. For this particular research, the three important building typologies that have been focused on comprise of temples (religious buildings), regional houses and monumental architecture. These are the key typologies which have been instrumental in giving the roots to regional and traditional buildings in India. There is a subtle translation of crafts seen on this kind of architecture, and it is one of the factors of creative expressions which will be looked into as well. It helps in understanding the association of reds and ways in which it is used in Indian buildings. In today's modern context when designers struggle to create regional essence in architecture, this study can be a base for understanding and implementing the spirit of color and materials in that context. It can be a base to compare the use of reds with the other architectural styles around the world.

25.1 Introduction

India is a vast expanse of varied topography and regional peculiarities. Architecture is largely driven by the attributes like local materials, topography, flora, fauna, climate and cultural fabric. The age-old crafts of India also have evolved as a result

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of these factors giving it a characteristic essence. Temples are the core examples of religious buildings created as oldest expressions of architecture. Regional houses comprise of the extremely grounded manifestation of the local materials and workmanship. Monumental architecture displays the most grand and royal expressions of built forms with the best craftsmanship and materials. Due to the vast use of reds in traditional architecture, the research focuses on identifying those colors falling in red family and understanding various aspects involved in it.

25.1.1 Methodology

The methodology followed for this particular research comprises the following steps:

(a) Key buildings from the different states of India as traditional Indian architecture (vernacular) were identified. They were categorized into three building typologies as religious buildings, vernacular homes and monumental architecture.
(b) The materials used in those buildings were identified with respect to their inherent color. Applied color was identified as an external layer of color on buildings. Both of these were studied in the context of the red color families.
(c) Observation, analysis and insights were drawn from the entire study. The common thread was pulled out as a rationale running across the specified building typologies with respect to the red color families.

25.1.2 Temples—The Religious Buildings of India

Temples of India are the oldest expressions of religious buildings and are largely seen to be made in different kinds of stone. The stone craft of India being one of the most ancient and sacred crafts reflects in the temples to a great extent. Stone is a natural material; its inherent color (color present naturally without any external or artificial application) comprises of tones like browns, beige, pinks, grays and black (Fig. 25.1).

As per the Munsell color wheel, the color families that are present in stones are present in the warm color gamut which falls in the range of yellow to reds.

25.1.3 Traditional Regional Houses of India

The traditional architecture of India is the true essence of being local and vernacular. Every region holds its own essence, and it is evidently seen in the materials used, the kind of structure made and its shape and form. The *Bhunga* house of

Sr. No.	Temple Picture	Temple name	Color desription	Image Source:
1		Somnath Temple, Gujarat	Beige stone with a pink tone	https://www.procaffenation.com/somnath-temple-demolished-reconstructed/
2		Konark Sun Temple, Orissa	Beige stone with layers of stones in pink, greys, browns.	https://detechter.com/this-13th-century-temple-in-konark-is-dedicated-to-lord-surya/
3		Jorbangla Temple of Bishnupur, West Bengal	Teracotta tiles cladded on the exterior. Terracotta red color.	Wikipedia commons
4		Jagannath Temple, Orissa	Solid massing of reds seen with whites and beige in combination	https://www.trawell.in/orissa/puri/sri-jagannath-temple
5		Mahabalipuram shore temple, Tamil Nadu	Beige stone with brown tones.	http://www.themysteriousindia.net/pancha-ratha/
6		Guruvayour Temple, Kerala	Teracotta red paint on walls, terracotta red tiles on roofs, and wood in combination with whites and beiges	http://blessingsonthenet.com/travel-india/destination/article/id/216/tour/id/28/temples-in-guruvayur
7		Khajurao Temple, Madhya Pradesh	Beige stone with layers of stones in pink, greys, browns.	https://www.culturalindia.net/monuments/khajuraho-temples.html
8		Trimbakeshwar Temple, Nashik	Black stone with brown layers.	http://www.findmessages.com/magnificent-trimbakeshwar-shiva-temple-nashik

Fig. 25.1 Key temples across India made in stone

Gujarat is one of the most basic and finest examples of local architecture. The structure is beige in color as it is made in mud (comprising of browns, off-whites) and embellished with mirror work on the walls to accentuate the openings. The color of mud belongs to the family of reds and browns. Similarly, the other vernacular typologies use locally available wood, mud, thatch and stone. Mud construction in many instances is layered with cow dung as it has antibacterial properties and is believed to possess positive energy. The use of decorative patterns and drawings on walls is significant manifestations of the joys of decorating and creating own houses. The materials like wood and stone being robust in their quality are used as structural materials (Fig. 25.2).

Sr. No.	Regional (traditional) houses	Typology name	Color desription	Image Source:
1		Wada of Maharashtra - Vishrambaug Wada	There is abundant use of wood, mud construction and stone. Terracotta red is also used as paint or as roofing material in few places.	https://blog.pune99.com/vishrambaugh-wada/
2		Courtyard house of south India	It is a similar kind of construction that is seen in the wada houses. It also comprises of the same materials	http://www.mangalaheritageretreat.in/testimonials.html
3		Bhunga house of Gujarat	Made in mud construction and thatch. The mud is locally procured material.	https://www.tripadvisor.in/LocationPhotoDirectLink-g3382545-d2620236-i86358706-Gateway_to_Rann_Resort-Kutch_Kutch_District_Gujarat.html
4		Tribal hut in mandana painting	Base of the mandana painting is in terracota red while the drawings are made in white	https://www.utsavpedia.com/motifs-embroideries/mandana-paintings/
5		Traditional Kerala house	The key element here is the roof structure made in terracotta manglore tiles. Wood is used in the entire structure along with stone.	https://www.pinterest.com/pin/384002305698517596/
6		House in Auroville	Sustainable building, climate responsive. Made in such a way that it looks like a sculpture. The structure comprises of terracotta red finish along with white paint.	https://www.flickr.com/photos/doctorcasino/5985315672
7		Tribal hut in Warli painting	Similar to mandana painting the base is terracotta red and the drawings are painted in white. The white paint is made of rice powder.	https://www.craftsvilla.com/blog/warli-art-history-maharashtra/
8		Pol House in Ahmedabad	Extensive use of wood is seen as a structural material. The walls are constructed in mud and painted in a suitable color, largely in beige.	https://www.tourmyindia.com/blog/tourist-attractions-in-gujarat/

Fig. 25.2 Traditional regional houses of India (vernacular)

25.1.4 Monumental Architecture of India

The monumental architecture of India, like the vernacular buildings, is inclined toward the use of traditional materials. Sandstone is used like a massing material throughout on larger areas and has its own natural beauty. There is an extensive amount of applied color as well, and it holds religious, cultural and symbolic significance. The art is a manifestation in the form of frescos, paintings, mirror work (*thikri*) and inlay work on the walls by local craftsmen (Figs. 25.3 and 25.4).

Sr. No.	Monumental Architecture	Name of building	Color desription	Image Source
1	 	City Palace Jaipur	The polychromatic display is accentuated in red color. The fenestrations are highlighted in terracotta red.	Self Clicked
2		Hawa Mahal, Jaipur	The entire buildimng is a terracota red structure, in sync with the pink city Jaipur. The opening deails are made to stand out in a lighter color i.e. whites. Some elements are painted in green.	http://www.carzonrentals.com/packages/same-day-jaipur-tour/27
3		Jawahar Kala Kendra, Jaipur	The building is made in red sand stone. It resembles the terracotta reds and whites are used for outlining some punctures in the building.	Self Clicked
4	 	Jaisalmer fort and palace, Rajasthan	It is largely a stone construction and the colors seen here are beiges and browns. The buildings seem to rise from the ground as if the topography itself converts into built forms.	http://www.jaisalmeronline.in/city-guide/jaisalmer-fort (left image), https://www.colourbox.com/image/patwa-haveli-jaisalmer-rajasthan-india-image-7043411
5		Amber for, Amber (Rajasthan)	The fort is beige in color whereas the decorative elements are seen to be painted in various colors. Red is used like black where there was a need for contrast. There are only a few colors used however the geometric patterns and color placements makes it look lik many colors are used.	Thakkar, Jay, 2010
6	 	Shekhawati Hawelis (Rajashan)	The havelis are a kaledioscopic display fo narratives. Reds are used to paint elements and also like a background color to the floral motifs.	https://www.pinterest.com/pin/274156696044699564/, (left image) http://www.india.com/travel/articles/the-fascinating-story-of-abandoned-havelis-of-shekhawati-in-rajasthan/ (right image)
7		Bundi palace painting, Bundi (Rajasthan)	Bundi paintings too are a display of various polychromatic colors. The reds have been used extensively in background as well as foreground. There is a warmth that is emoted from these paintings.	http://www.solobackpacker.com/tag/bundi-school-of-art/page/2/

Fig. 25.3 Monumental architecture of India (iconic)

25.2 Observation and Analysis

The use of reds as described earlier is categorized in inherent color and applied color as follows:

(a) **Inherent Color**: The color of natural materials without any other external color application is known to be the inherent color. These materials of the vernacular architecture largely comprise of stone, wood, terracotta, mud, lime and bricks. They become common denominators across all the three building typologies. Their tones vary as per the geographic location because they are all naturally available materials used locally. It is a palette of browns, terracotta reds and beiges which form a very natural color palette as inherent colors of the

Sr. No.	Monumental Architecture	Name of building	Color desription	Image Source
8		Baroda Palace, baroda, Gujarat	The palace is constructed in stone carved with itricate details and motifs. It is a combination of greys, beiges and browns	Self Clicked
9		Humayun's tomb, New delhi	This is a structure in terracotta reds which is typically the color of the stone used here.	https://www.mapsofindia.com/my-india/travel/a-mughal-masterpiece-humayuns-tomb/attachment/humayun-tomb-delhi
10		Taj Mahal, Agra	Taj Mahal is built in white marble. The other structures in its premises starting from the entrance are made in red sandstone. Amongst the teracotta and reds of the structures in the periphery of the premise, Taj Mahal pops up like the white shiny monument.	http://www.cpreecenvis.nic.in/Database/TajMahal_5308.aspx
11		Qutub Minar, Delhi	This towering structure is extensively made in red sand stone. One leve towards the top is also made in white marble in a smaller proportion of white as compared to the reds.	http://www.wikiwand.com/en/Qutb_Minar
12		Padmanabhapuram Palace, Trivandrum	The palace is a very muted structure in whites at the base, however the roof structure and other structural elements are largely made in wood. The roof skin is terracotta tiles.	https://www.pinterest.com/pin/377246906263978248/
13	 	Mysore Palace	It's a muted building in whites and beiges. A pop of red has been used to accentuate the domes of the palace giving a sense of monumentality.	Wikipedia commons (left image), https://www.dreamstime.com/royalty-free-stock-images-closeup-southern-towers-beautiful-domes-mysore-palace-image28622969 (right image)
14	 	Taj Mahal Hotel, Mumbai	Similar to the Mysore palace, the domes of the structure are accentuated with reds (mostly resembling the terracotta red color). The rest of the structure is a muted stone construction with subtle earthy grey colors.	www.yatra.com (left image), https://www.cntraveller.in/story/mumbais-taj-mahal-gets-trademarked/ (right image)

Fig. 25.4 Monumental architecture of India (iconic)

materials used. Earth pigments have been widely used from ancient times till date, and India has an important historical background for the use of ochers and clay pigments in arts.[1]

Stone is used as the main building material in the religious building typologies. Terracotta tiles are used as roofing elements in homes to keep the temperatures in the interior of the houses cool. They are also used as cladding materials externally on the *Jor-bangla* temples of *Bishnupur* with intricate craftsmanship from clay. Terracotta pots are used in filler slabs which give cooling effect. These constructions are kept raw and not colored, the beauty being its rawness. The colors in temples largely comprise of inherent color of stone because it is the key material used in its construction. The narration of stories is done on the temple buildings through the medium of stone craft, and it is one of the oldest forms of aesthetic representation. Its beauty lies in the finesse of the workmanship and manifestation of narratives. The inherent color of various kinds of

[1]http://www.kfpe.ch/projects/succes-stories/electronic_appendix/cavallo.php.

stones used in temples all over India gives every temple a different natural tone and architectural expression. Regional houses are also made in local materials (with their inherent color intact), and use of applied colors happens only in the scenario where there is decoration or ornamentation required.

(b) **Applied Color**: The use of applied color is used to emphasize the shapes and forms in architecture. Red is one of the important colors largely used along with the other hues. Use of terracotta reds is an outcome of materials like earth/mud/clay used in building construction since antiquity (the most easily available local material). Red has apparently translated into one of the major hues of applied color (for massing as well as for decoration).

   i. **In Monumental Architecture**: In monumental architecture, use of applied color is seen in various areas and elements. The monumentality of these buildings is demonstrated through such expressions and grandness in the scale. In miniature paintings and frescoes of the iconic architecture, there is an attempt to use persisting local crafts and techniques. The best examples of its use are seen in the Shekhawati palaces and in the palaces of Jaipur. *Geru* (red ocher) is one of the most widely used colors in the paintings of Rajasthan (Jaipur).
   Red is used for emphasizing elements like the domes of Mysore Palace (pop of deep rich red). Similarly on the Taj Hotel in Mumbai, the domes have terracotta red color in contrast to the subtle grays and beiges of the building. This kind of color decision has accentuated their monumentality. There are certain influences from Mughal architecture and geometry in the practice of applied color to this kind of building typology.
   ii. **In Traditional Homes**: Decorative colors in traditional homes are smaller in scale and percentage as compared to the palaces. However, they are beautifully manifested as self-expressions by the people who live there and practice the local crafts. The paintings like *Mandana, Warli*, *Gond* are seen in the regional houses (these paintings are basically the local art forms).

Red as an applied color is symbolic to vibrant energy, fertility and a sacred color which holds importance in architectural embellishments and decorations. The *Vishnudharmottara* suggests that a color called *Igur* was used to delineate the image of fresco paintings in India as it is one of the visually boldest colors after black. The *Abhilasitartha–Cintamani* also mentions *sona*, red from *darada* which is an early name of cinnabar.[2]

In *Ayurvedic* traditions in the subcontinent, mercury (red) and sulfur (yellow) are attributed, respectively, to *Shiva* and *Kali*, the elemental male and female principles of the Hindu pantheon. With reference to painting, sublimated cinnabar crystals

[2]Desomns, Peter Lazaro, *Methods and Symbolism in the Picchvai painting tradition of Rajasthan*, Mapin Publishing, 2005, p. 35.

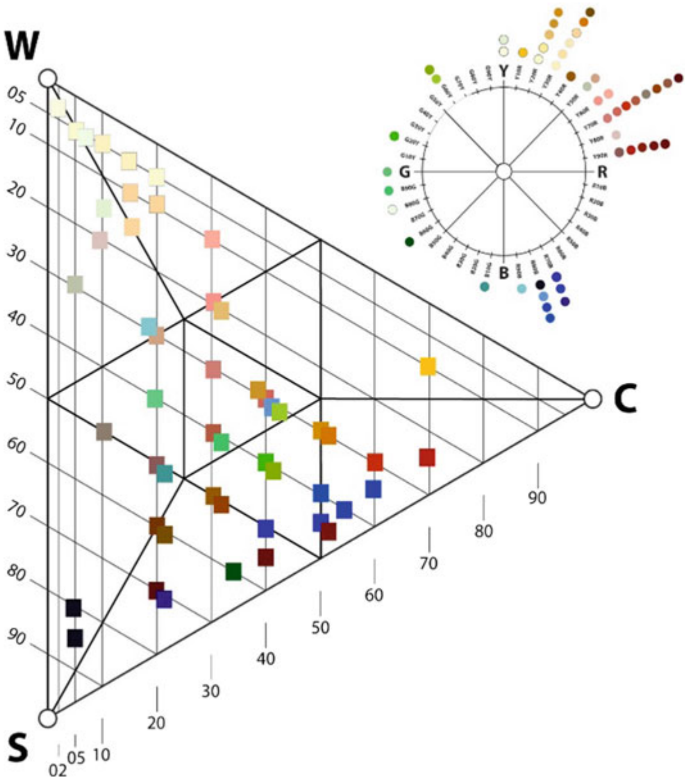

Fig. 25.5 Natural color system (NCS) 3D color space showing colors in Jaipur palaces. It shows all the colors in one Munsell color wheel. The use of the red color families is the most evidently used color family. *Source* Sonar, Saili, *Color configurations of Jaipur palaces*, AIC 2011—Association Internationale de la Couleur, Zurich, Switzerland

were ground into a brilliant red pigment, known in Europe as vermilion and in Sanskrit as *Hingaloo.* Lac was also used in the miniature paintings to outline the images in manuscripts.

Geru (red ocher) is one of the most widely used colors in the paintings of Rajasthan.[3]

Lighter colors like the beige and browns are used for color massing on larger surface areas. This creates a neutral backdrop for the layers of colorful punctuations in both the typologies. There has been an attempt of replicating the colors of natural stones (e.g., sandstone) which gave rise to the brown or reddish brown hues which were externally applied to the focused building typologies (except the temples) (Fig. 25.5).

[3]Sonar, Saili, *Colors in Indian context: The tangible and intangible perspectives of color pigments in Indian Paintings*, AIC 2011—Association Internationale de la Couleur, Santiago de Chile.

This is one example of color mapping in architecture which shows an empirical analysis of the presence of red color families in the palaces of Jaipur. The colors on those buildings are captured scientifically and are mapped in the NCS color triangle. The presence of terracotta reds, pinks and red pigments is used widely.[4] There is a presence of terracotta reds, pinks and red pigments which is wisely used.

25.3 Conclusion and Further Study

Red is supposed to be not only a sacred color widely used in architecture but also an important color of Indian culture, traditions and craft. Color does not exist in isolation, and hence in vernacular architecture it exists along with the different forms that the building possess. While creating the vernacular buildings, the instinctive sense of foreground and background is seen where reds manifest in different tones. Also, there are extensive expressions of the local crafts on the buildings as a creative and personalized gesture. Indian crafts and paintings are demonstrated on the buildings which add value to the already existing Indianness that these sustainable buildings hold. Here, crafts are seen in the form of wood carvings, stone carvings, paintings, frescoes and the craft of creating the structures (craft of architecture). The underlying essence is that there has been a sustainable approach to create the buildings with strong purpose. While doing the same, the rawness of materials and their textures and colors are respected and have their own position and identity in architecture. The earth pigments and natural materials have created the default red tone. This is evidently seen in monuments of Jaipur, the forts and iconic buildings of Delhi, earthy architecture of Kerala, the stone architecture of Rajasthan, mud architecture of Gujarat and meticulously made sustainable buildings in Auroville. In wall paintings, the use of cinnabar as a red pigment has an important significance with a history that dates back to third century BC. It is a warm color and works well visually to create depth and focal points.

The way in which reds are used can be called as a sustainable approach towards color. It has certainly been a result of sustainable building methodology and creative expressions of space-making crafts. Unlike the modern buildings today where a mandatory external paint is needed, the historic architecture (or heritage buildings) did not feel the need of this compulsion. Wherever there was color used in decoration, that has been used as an informed decision giving crafts a pedestal position along with the same. This approach can be used while designing buildings in today's context for their colors irrespective of the building being a modern or a traditional typology.

[4]Sonar, Saili, *Color configurations of Jaipur palaces,* AIC 2011 (Association Internationale de la Couleur), Zurich, Switzerland.

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Chapter 26
Influence of Visual Elements in Building Facades in the Formation of Experiential Perception

Anita P. Yammiyavar and Madhumita Roy

Abstract Building façade, as a communicating interface between inner and outer building spaces, is mostly a matter of evaluation by visitors. Perceptions are formed by the building's facade, its entrance, atmospherics and ambiance. Some elements create positive perception in the user's mind, while some others may leave a negative impact. Along with a set of shopping experience questions, participants were shown shopping mall facade images. They were asked to identify building features that contributed to forming of their perceptions of the shopping mall experience. The analysis indicates that specific architectural facade design features like entrance door, size of openings/display windows, approach path, parking bays, crowd density equally influence the formation of perception. The inferences aid heuristics of designing shopping mall facades.

26.1 Introduction

Building façade, as a communicating interface between inner and outer built spaces, is a matter of visual evaluation by visitors. Perceptions get formed by the visual impression made by the building façade. A series of designed elements in the façade come into perceptual play in creating the expectations and apprehensions even before entering the building of a new shopping complex. Way back in the 1960s, urban designer Kevin Lynch [1] emphasized the role of visual elements in cognition of urban space. In Lynch's definition of image as 'a picture especially in the mind', it is a result of a sentimental combination between objective city image

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and subjective human thoughts. Some building features create a positive attitude and perception in the user, while some others leave a negative impact.

Retail sector growth of up to 14% per annum of late is observed in Indian small towns urbanizing rapidly into cities. Most expansion in retail sector has been achieved by converting or refurbishing the existing buildings which were not necessarily built as large retail malls. Architects are often confronted with designing facades of such buildings. What could be the design strategy for a façade which is functional and relevant and also successfully creates the desired perception in users, given the competitive marketing and sales scenario in the rapidly expanding retail sector? Why are some shopping malls more liked than others? Can the shopping mall's visage play a proactive role in the formation of positive perception? At what point of time and using which visual elements can an architect achieve balance between novelty versus familiarity versus continuity of the malls' perception held by a faithful regular shopper? To explore these questions from an architect designer's point of view, a study was conducted to understand preferences and assimilated experiences of shoppers.

26.2 Literature Study

India has been ranked fifth of the thirty emerging retail markets of the world by the global real estate consulting group Knight Frank [2]. Initially, these organized retailing formats were mainly established in metropolitan cities and are now springing up in smaller towns. The word 'mall' as used in this paper is used synonymously to shopping complex, shopping enclave, shopping arcade.

Several researchers Houston and Nevin [3]; Sinha and Banerjee [4]; Baker and Haytko [5] have investigated the image aspects of shopping malls. Shopping mall image plays an important role for customers while choosing between different competitive shopping malls. Researchers like Doyel and Fenwick [6] have shown that store image plays an important role for customers while choosing between different competitive shopping destinations. If a visit has left a positive salience towards liking the experience, chances of a repeat visit increase and every visit reinforces past positive perceptions. In their study, Hirschman [7] has shown that store image influences loyalty of the customer towards rating satisfaction. Bearden [8] indicated price, merchandise quality, assortment, atmosphere, location, parking facilities and friendly personnel as the characteristics affecting the store image. All the researchers above have focused on finding out correlation of shopping mall quality features to preference and ratings of consumers. In all these papers, the subject of study is more on correlations of shopping mall image and what will increase commerce. They are silent on correlating architectural design features and satisfaction levels.

Malls in India are increasingly becoming alternative entertainment leisure spots for urban middle class whose expectations of a mall have gone beyond the sole functional act of shopping. They are now becoming social interaction spaces.

Designing interiors, ambiance, facades of shopping malls has come into its own as a specialized track within architectural design. Published papers in the retail sector do not go in depth on the design features of the built form themselves, resulting in a knowledge gap for architects and builders. Other researchers who have published in this area such as Passini [9] have dealt with store layout, direction and wayfinding and their effect on consumer's choices but not on design proper.

Peponis et al. [10] have dealt with the formation of spatial meanings in architectural design. However, their examples are confined to doors, pathways and connections 'within' a building. Their research brings in a different angle that of syntax, to the formation of meanings by space. Their approach has potential to be applied to spaces in 'front' (façade and approach space) of commercial buildings. Yet in another interesting paper on application of perception by architects to buildings, researchers like Llinares and Page [11] have analysed customers' emotional responses to real estate promotions by using Kansei Engineering techniques. The authors have collected data and identified the main independent concepts or attributes which describe the property purchaser's perception in his own words. It is pertinent to notice that none of the 15 factors taken into consideration dealt with the facade or the space in front of the building or on any visual architectural element such as form of the building. Therefore, there is a dearth of information on the role of visual elements on the facade of a building and their influence on perception formation which this paper intends to address.

In a paper titled Influence of Building Façade Visual Elements on its Historical Image, Askari and Dola [12] have worked on the city of Kula Lumpur. They were studying the impact of facades specifically of historical buildings on the posit that inconsistency amongst the elements of historical building facades has overall negative impact on the image of the area as well as the city. A finding of their study indicated that architectural style and colour were the visual elements that mostly influenced the images of historical buildings.

Gosh et al. [13] have studied the case of Kolkata city while evolving a methodology for application of visual perception of an urban place. According to them, visual perception has a substantial bearing on cognition, impression and importance of an urban place. The authors have attempted to find commonalties in the two design approaches—viz., visual communication design approach and urban place-making approach that have gone into Kolkata's urban development. They argue for a holistic interrelationship between the visual communication aspect and the spatial place-making aspect of an evolving urban place. Their analysis of results shows that apart from buildings other elements of urban design such as signage, advertising, street furniture play a key role for visual perception of a place. They concluded that the visual perception of the environment affects our actions, reactions and feelings. While the conclusions strengthen important role of visual perception, how exactly these visual communication elements and which one of them matter in designing are not touched upon by the authors.

Arnheim [14] has stated that form and content are indivisible and that the patterns created reveal the nature of human experience. For architects and built environmental designers, the understanding of how design elements can be utilized on the mall facades to create a desired experiential effect for the mall user becomes important.

From the literature study and the gaps identified, the following research questions arise: What are the facade design elements and features that matter in the formation of perceptions that lead to the liking or disliking of a built space? Which facade elements contribute to the formation of these perceptions and in what weightages? This paper attempts to seek answers to these questions by capturing, analysing and understanding users' perception through a questionnaire and image boards.

26.3 Methodology

A questionnaire in two parts was formulated to elicit responses of regular visitors and users of commercial shopping malls. Part A of the study contained 18 items focusing on rating experience of shopping malls in general without referring to any particular building. Part B collected responses to a set of visual cues in the form of pictures. Part B involved choosing and ranking pictures of shopping mall facades for their likeability and identifying facade features which went into the formation of percepts such as 'like' or 'dislike'.

In Part B, respondents were asked to choose five most liked and five least liked building facades from a set of twenty shopping mall pictures chosen from a sample set of random 50 shopping mall facade pictures from open sources on the net and retail trade magazines. Shopping malls from medium-sized urban Tier 1 and Tier 2 towns and from metros were chosen to cover all geography regions of India. Since the focus was on front facades, approach path, setback distance and view from road, a panel of three architect interns were asked to choose 20 from the total set of 50 pictures. The criteria were independent full shopping complex buildings meant and built only for the purpose. Later, these 20 were individually compared to each other by the author so as to eliminate similarity and selected based on differences. A sample size of forty (40) respondents was asked to rank them in order from first rank to fifth rank in terms of their liking of building's designs. Further using a transparent overlay sheet over the ranked building pictures, respondents were asked to mark such of those areas on the ranked building that contributed to their liking/disliking of the buildings. Keeping the length limitations of the paper, only responses of the first-ranked 'most liked' and first-ranked 'least liked' building have been presented hereafter in this paper. Part B was designed to elicit affective design components such as aesthetics, ambiance, atmosphere and features of the physical building complexes that contribute to perception formation.

The sample size of respondents for Part A survey was 34 and Part B was 40. Respondents on two national university education campuses were approached randomly. Willing respondents were informed of their rights and assured privacy protection of their personal data before obtaining their consent. Table 26.1 shows some of the demographic details of the responding sample.

Table 26.1 Sample size characteristics

	Subgroups	Sample size Part A	Sample size Part B
	Total sample size	34	41
Gender	Female	16	20
Gender	Male	18	21
Age	<=25	22	28
Age	>25	12	13

26.4 Analysis and Inferences

26.4.1 Demographic Characteristics

From the collected demographic data of the respondents, it is observed that the younger age group not only forms a major chunk of regular visitors but also frequents malls more often than other age groups (Fig. 26.1). An explanation could be that malls are increasingly being preferred by young as socializing leisure spaces. Respondents had experience of shopping in all urban cluster size categories ranging from small towns, mid-sized towns, cities and metros, indicating that all categories of urban settlements visited were represented by the sampled population (Fig. 26.2). Perceptions, likes and dislikes, opinion and needs of the younger generation, rather than the mid-age generation, are likely to influence more on how such malls ought to be designed.

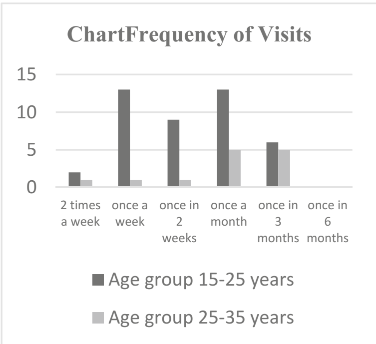

Fig. 26.1 Age and frequency of visit

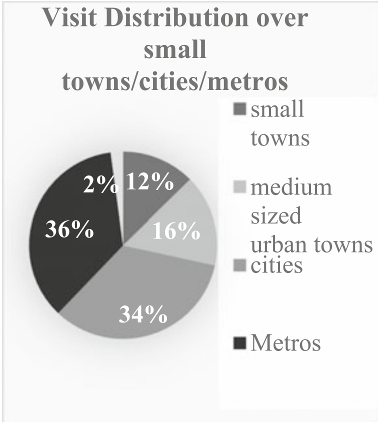

Fig. 26.2 Visit distribution over cities

26.4.2 *Inference from Part A Questionnaire: Influence of Experiential Variables Influencing the Formation of Perception*

Respondents were asked to rate the importance of 18 parameters of shopping mall experience on a ten-point scale. They were asked to assign points from 1 (minimum) to 10 (Maximum) indicating importance in their judgement, these parameters have on formation of perception and experience. The 18 features were identified based on them being related to two main categories contributing to the formation of total experience—(a) outside the shopping complex just before entering and (b) experiential features inside the shopping complex, after entering. 'Outside the mall' category sought the rating importance of building aesthetics, building approach path, vegetation, landscape and entrance area. The second category was intended to cover factors inside the mall such as ambiance, facilities, service and quality of visual interiors.

Of the 40 respondents in the pilot survey, responses of 6 self-filled questionnaires had to be discarded due to incomplete or illegible/multiple entries. Thirty-four numbers of respondents' data were found valid to statistically process their ratings on the ten-point scale and get their mean weighted values for each feature as shown in Table 26.2.

Even though the sample size was small, in order to discern early patterns if any, in the ongoing data collection, an analysis of correlation amongst the 18 items for a sample size of 34 yielded the items that had marked correlation ($p < 0.01$—lower the p value, higher is the significance level) indicating that the experiential factors (item numbers 4, 6, 7, 11, 13, 14) and design factors (1, 3, 9, 5, 10, 12, 15, 16, 18) probably strongly influence each other in the formation of perceptions of shopping malls' sum total experience. Between the two categories—(a) experiential factors and (b) design factors—there was a significant correlation (see Table 26.3). Further average weighted values of means of the two broad categories—internal

Table 26.2 Items with mean weightage and ranking

S. no.	Features	Q number in the item list	Mean weighted values by respondents for each question	Priority rank of importance as inferred by the weightages
1	On a mall necessarily having food/ eating counters	13	0.82	1
2	Service quality of sales personnel	6	0.79	2
3	Freedom to touch/examine products whether you want to buy or not	4	0.77	3
4	On general ambience such as lighting, music, colours, Ads, displays	5	0.76	4
5	Interior layout & movement flow	2	0.76	4
6	On a mall necessarily having cozy corners for resting tired feet	14	0.76	4
7	On quality of interiors, ambience, music lighting	3	0.75	5
8	Time taken to pay and exit the mall after shopping	7	0.73	6
9	Building Architecture looks before entering	1	0.71	7
10	On the need for low noise level within the mall so as to have a quiet experience	15	0.68	8
11	On existence of plants/landscape/garden /waterfall in the mall	18	0.68	8
12	On the need to have lower density of visual advertisements/ displays within a mall.	16	0.65	9
13	Ratio of area for circulation (movement) space around the displays and counters	12	0.64	10
14	On the degree of futuristic design of the interiors	9	0.63	11
15	On irritants like security checks, exit check of bags after shopping and paying, intruding into private space	11	0.61	12
16	On the existence of a children play area in the mall	17	0.61	12
17	On how ethnic & Indian the interiors are	8	0.59	13
18	On how close the mall resembles malls in foreign countries	10	0.53	14

Table 26.3 Correlations table between two categories of factors

		Experiential factor	Design factor
Experiential factor	Pearson correlation	1	0.713**
	Sig. (two-tailed)		0.000
	N	34	34
Design factor	Pearson correlation	0.713**	1
	Sig. (two-tailed)	0.000	
	N	34	34

**Correlation is significant at the 0.01 level (two-tailed)

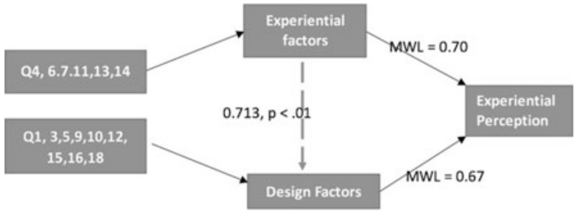

Fig. 26.3 Relationship between experiential group of factors and design group of factors

experiential factors and external design elements—as derived by collating from Table (26.2) are as follows (Fig. 26.3):

$$\text{Experiential factors (item numbers } 4, 6, 7, 11, 13, 14) = \mathbf{0.7033}$$
$$\text{Design features (item numbers } 1, 3, 5, 9, 10, 12, 15, 16, 18) = \mathbf{0.67}$$

Inferences can be drawn from the above analysis of data under Part A as follows—notable correlation is observed between external building design factors and the interior experiential factors. This implies that an architect cannot afford to either neglect set of factors or give importance to one over the other. Both these are correlated and influence the sum total perception formed in a user. Even though the internal factors were mean weighted slightly more than the building factors, the significantly strong (0.713, $p < 0.01$) correlations between them indicate that there needs to be equal design emphasis on both. Neglecting one or giving less importance to either one would probably influence negatively the formation of sum total perception of a frequent shopper. It therefore can be posited that architectural design of the building façade, which is the visitor's first visual contact with the shopping mall, is likely to become a significant 'sign' for semantically communicating meanings and the anticipated sum total experience inside it. In other words, architects could iterate the semantic meaning of the facade's visual composition so as to be able to create a desired perception in the visitor for the anticipated experience inside a mall.

26.4.3 Inferences from Part B Study—Features and Elements in the Physical Building that Contribute to the Formation of Perceptions

The visual architectural elements on the facade of the building act as meaning communicators in the form of semiotic symbols and signs of the anticipated experience awaiting the user. Architects are aware that if there is dissonance between the look and the feel of the facades on one hand and the quality of the anticipated experience, once inside, it is likely to reduce the 'likeability' salience due to the formation of below optimal perception levels in the user. Which and what type of facade element acts as a sign and which visual design element leads to meaningful emotional engagement, if known a priory, could aid the architect while designing.

In order to find out specific visual elements on the frontage of the facade that possibly have a positive salience on forming 'likable' perceptions on the one hand and isolate the features that contribute to negative salience on the other hand, these 40 respondents were asked to choose five 'most liked' and five 'least liked' shopping building frontages from a set of 20 shopping mall buildings. Further, for the five best-liked facades, respondents were asked to visually point out, by marking a circle around the individual features they liked and features disliked on the five 'least liked' designs. Due to space limitation results of only 2 ranks of the most liked buildings and 2 ranks of most disliked building is reported and discussed in this paper. Out of the 40 respondents, 16 respondents have ranked the façade (building number 13 in Table 26.4) as 'Rank 1' amongst the most liked 5 buildings. Building number 4 has been ranked as number 1 in the least liked category (Table 26.5).

A visual analysis of the markings of the highest ranked 1st and 2nd "liked' building (Fig. 26.4) done by the respondents—it is observed that some building features such as Entrances, Approach paths, Visual line of sight, Upward perspective—have been repeatedly marked by the respondents as to features they 'liked'.

Open space at the entrances of the complex, visibility of interiors through the display windows, visibility of the main entrance door, depth of the building, a welcoming protective deep recession of the entrance flanked by the symmetrical left and right sides are observed. The presence of a structural roof element that supports transparent roofing is seen to be marked in all three pictures. When the least liked buildings ranked first and second, it is observed (Fig. 26.5) that crowded front space, parking bays, crowds, inability to locate entrances to the complex have been marked as the features not at all liked. The markings in a way are opposite of those features that have been marked in the most liked building facades (Table 26.6).

As observed in Figs. 26.4 and 26.5, most frequently marked building design elements by respondents are listed below.

Table 26.4 Most liked shopping building facade ranks

First	Second	Third	Fourth	Fifth
13 	10 	17 	18 	3 

Table 26.5 Least liked facade ranks

First	Second	Third	Fourth	Fifth
4 	9 	16 	2 	12 

Fig. 26.4 Markings showing identified features of the first two ranked buildings as most liked. Length limitations of paper constrain use of bigger scaled pictures

Fig. 26.5 Markings on first two shopping buildings ranked as least liked

Table 26.6 Frequently marked design element/feature

1.	The entrance door
2.	The approach walk/space with steps indicating higher point of visual perspective
3.	The extent of depth of the building in terms of its size, volume, largeness
4.	Glimpse of insides of the building—large shopping display windows
5.	Landscape features—vegetation, lighting
6.	Location of entrance door—in the centre making wayfinding not a challenge
7.	Size and scale of entrance door—with overall scale of the building
8.	Symmetry of the entire structure along with the overhanging roof feature that semantically affords protection
9.	Crowd
10.	Non-discerned entrance approach with barriers
11.	Entrance door not in proportion to overall building
12.	No display windows to see what is inside the building—instead covered by large visual hoardings
13.	Parking bays and traffic in the front

26.5 Discussion, Limitations and Conclusions

From the analysis of responses, it can be inferred that both external experiential building features and internal design features are correlated and influence the sum total perception formed in a user. Even though the internal factors were mean weighted slightly more than the building factors, the significantly strong (0.713, $p < 0.01$) correlations between them necessitate that there needs to be equal design emphasis on both.

To the question raised as to what are the elements that matter in the formation of perceptions that lead to the liking or disliking of a built space, the results indicate that specific visual elements on the frontage of the building facade that possibly have a positive salience on forming 'likable' perceptions are (a) the entrance door and its characteristics such as size, scale, location at a higher point of visual perspective; (b) depth of the building volume probably indicating the presence of large interior spaces; (c) glimpses of the inside of the building at the approach point of view; and (d) extent of the property of symmetry of the building. The front facade is as important as the interior in the formation of a user's perception based on which the sum total experience gets accumulated towards either like or dislike.

This being a pilot study the small sample size is a limitation. So as to get a more detailed understanding of the various experiential and environmental attributes that contribute to perception formation, a detailed questionnaire consisting of 64 questions has now been developed and will be administered to a larger sample size in future as part of this ongoing research in architectural design.

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Chapter 27
Visual Culture of Urban Spectacles: A Discourse on Festivals in the Light of Urban Semantics

Anusmita Das and Amarendra Kumar Das

Abstract Every city has its own identity and culture manifested through its people and activities that occur in its urban spaces. With advancements in technology and globalisation, there has been a mass influx of people in urban environments. This has led to the confluence of ideas, philosophies and culture, while stretching and challenging the psychological and physical boundaries of cities around the globe. Cities are the physical manifestations of such paradigm shift, thus becoming hubs of cultural expression which are notably rich in visual culture. In this regard, the city can be viewed upon as a palimpsest which constantly adapts and redefines its meanings over time as a result of a conglomeration of multiple intermingling discourses. As urban spaces gain new meanings and functions with changes in cultural practices, a city can no longer be seen as unidirectional but fluidity and temporality are observed as some of the key aspects. Urban spectacles such as festivals provide some interesting insights in this regard. In a time where change is the norm, a foray into the visual culture of urban spectacles can give a multidimensional view on urban semantics by analysing the three main dimensions of urban space: functional, aesthetical and symbolic. This paper will foray into the domain of Urban Semantics through the study of festivals by bringing together semiology and the urban. It will also analyse the role festivals as temporal marker, spatial marker, narrative fortifier and visual identifier.

27.1 Introduction

Urban spaces and environments are multidimensional and are inherently complex, dynamic and transformative in nature [1–7]. These urban spaces in cities are many layered and offer a rich narrative discourse on aspects of socio-spatial perspectives.

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In the present times of change due to advancements in technology and globalisation, the urban fabric of cities has undergone transformations repeatedly, which seems like the norm. The confluence of new ideas, philosophies, culture manifested through people and activities that occur in urban spaces has challenged the psychological and physical boundaries of cities, transforming them into hubs of multicultural expressions. The study of cities thus calls for a reorientation of the traditional perception of cities to include not just the physical fabric, or the tangible, but also the intangible representations that occur in its environment. The manifestation of such a paradigm shift in understanding cities can present new insights on meaning making through the study of interaction of people and urban spaces. The ongoing debates and growing interest in urban transformation and the disparities surrounding it in recent years have invited the attention of not just social scientists but also architects and urban researchers to try and understand the various factors affecting the urban landscape from social, economic, political and cultural processes. In this regard, the city can be viewed upon as a palimpsest which constantly adapts and redefines its meanings over time as result of a conglomeration of these multiple intermingling discourses. While from afar, cities appear to be complex, dynamic and abstract; they can still be perceived as an ensemble of meanings through the everyday interactions and events that take place within them. Urban festivals are one of the ways through which meaning is imparted to the urban fabric. In India, where festivals are a way of life, these events have heightened importance both in the social and spiritual life of its people. Festivals such as Durga Puja, Diwali and Ganesh Chaturthi have transpired as the phenomenon of Indian cities and are important in shaping the urban environment and people's idea of a city [8]. As urban spaces gain new meanings and functions, a city can no longer be seen as unidirectional but fluidity and temporality are observed as some of the key aspects. Urban spectacles such as festivals provide some interesting insights in this regard. In a time where change is the norm, a foray into the visual culture of urban spectacles can give a multidimensional view on urban semantics by analysing urban space as not just functional and aesthetical but also considering its symbolic dimension. Cities as a symbolic text become an inscription by the people and activities contributing to the visual urban imagery, one that operates as both a product and producer of changes in the urban fabric [9]. There is however an ambiguity regarding the character of present-day Indian cities with new meanings emerging and no methodical study to understand them. As festivals continue to emerge as the symbolic image of the urban Indian condition, a study was imperative to understand the emergence of new meanings in Indian cities in this context. An understanding of these diverse facets that exist in cities is imperative both in praxis and formulation of theory on how urban spaces can be analysed and studied [10]. This paper will foray into the domain of urban semantics through the study of a yearly festival in Guwahati, India, by bringing together semiology and the urban. It will also analyse the role festivals as temporal marker, spatial marker, narrative fortifier and visual identifier.

27.2 Methodology

By studying the annual festival of Ambubachi Mela in Guwahati, as temporal, spatial, narrative and visual/symbolic representation of the urban fabric of the historic core of the old city, the paper delves into the meaning attributed to the urban form through the various rites and rituals of this festival. While exemplifying its role in the formation of collective memory and place attachment, the paper seeks to convey the process of urban imagery and urban identity through the study of these processes. By using qualitative mapping, go-along methods, participant observations, open-ended interviews, photography and document analysis, the fieldwork of the research was carried out. The research sought to analyse the accommodation of the various narratives and interpretations in the historic core of the city spatially and visually through the morphology of this annual festival. The analysis of the various collective experiences involved in the creation of these urban spectacles would aid in the understanding of the creation and transformations of urban spaces within the organic form of the city of Guwahati. The merging of the denotative and connotative aspects of the festival is a part of the urban imagery which would contribute towards the understanding of the visual culture of urban spectacles as this festival has its roots in the origin of the city.

In her seminal work titled *Urbanism and Semiology*, Françoise Choay (1969) [11, 12] developed a technique aimed to connect empirical analysis of architecture with narratives that are spatial in their manifestations. Her work can be interpreted as a strategy that can throw light on urban form and narratives in the light of urban semiology. The spatial–temporal narratives can be read through the various approaches developed in her work such as through (1) architectural/spatial organisations, (2) ancillary systems in usage (symbolisms, rituals, activities, etc.) and (3) syntagms —the relationship of various patterns in relation with each other and the whole. The concept of 'semantically weighted elements' was introduced by Françoise Choay [11, 12] showing the relationship between urban elements within the urban fabric. A primary element represents a place of local prominence which plays a definitive role in the development in a given zone. These elements may not be of historical in nature, but based more on their relationship with their surroundings which might go beyond their physical significance. These elements aid in reading an urban space and gives insight into how the urban fabric evolved over time. This research paper will however deal with the ancillary systems that are inscribed in such primary spaces and analyse their role in the formation of the primary elements.

27.3 Urban Fabric of Guwahati: The Historic Core, Transformations and Urban Growth

Guwahati, once known as Pragjyotishpura (the Light of the East), is the capital city of Assam in the north-eastern part of India. Guwahati derives its name from the Assamese words 'Guwa' meaning areca nut and 'Haat' meaning market. It was previously known as 'Gauhati' during the British era. The city lies on the banks of the Brahmaputra and the foothills of the Shillong Plateau. Traditionally, Guwahati has been an important administrative and trading centre and a river port. As any other city, Guwahati has grown though migration in different periods in history. The 1971 census showed that 59% of Guwahati's population had migrated to the city [13]. There has been rural–urban migration from within the state, interstate migration with large proportion from Bihar, West Bengal, Rajasthan, Meghalaya and Uttar Pradesh, intra-state migration from other districts of Assam and a majority of international migration from Bangladesh and Nepal. Despite being the capital of Assam, Guwahati has a very low level of urbanisation as compared to other states of India. In the last decade, that is, 2001–11, the urbanisation rate slowed down to 2.5 per cent p.a., which is lower than that of India (of 2.8% p.a.) [13]. One of the impediments to the development of the urban fabric of Guwahati is the geo-hydrological features of the city itself. The river Brahmaputra runs along the entire length of the city and thus most of the older core administrative and commercial areas developed along its banks. Later on, the capital complex of Assam (the Secretariat) was developed in the south-east of the older core area connected by a single link road. A critical evaluation of Guwahati's street network by Hemani and Das [14] highlights the fact that the city has poor connectivity as there are only a few major roads, while the arterial roads are mostly dead ends, resulting in reduced permeability and increased stress on major routes. As the city is flanked by hills all around and forms a valley, expansion is restricted in most areas which could be the reason impeding a proper street connectivity layout. The migration of different cultural groups into the city over time and their certain economic activities and the attachments to ethnic, religious and linguistic identity have manifested in the form of many community centric settlements [13]. This has led a multifaceted identity to Guwahati City. The morphological transformation of Guwahati over the ages can be studied under the five stages of history: (1) Mythology, (2) Ancient period (fourteenth to twelfth century AD), (3) Medieval period (thirteenth to eighteenth century AD), (4) Colonial period (nineteenth to mid-twentieth century AD) and (5) Modern period (mid-twentieth century AD to present times). The transformations of the city as a result of economic growth and a by-product of globalised elements has influenced the city to reimagine its form, symbols and monuments as a global city inscribed in history. Guwahati has been selected by the Ministry of Urban Development, Government of India, as one among 98 Indian cities which will be upgraded to smart cities in the coming times. But in present times, Guwahati represents a composite form developed through various decades of population influx and shows a spectrum of varied urban typologies and social patterns that developed in response to the reasons mentioned above and hence can be described as multilayered at the best [14] (Figs. 27.1, 27.2, 27.3 and 27.4).

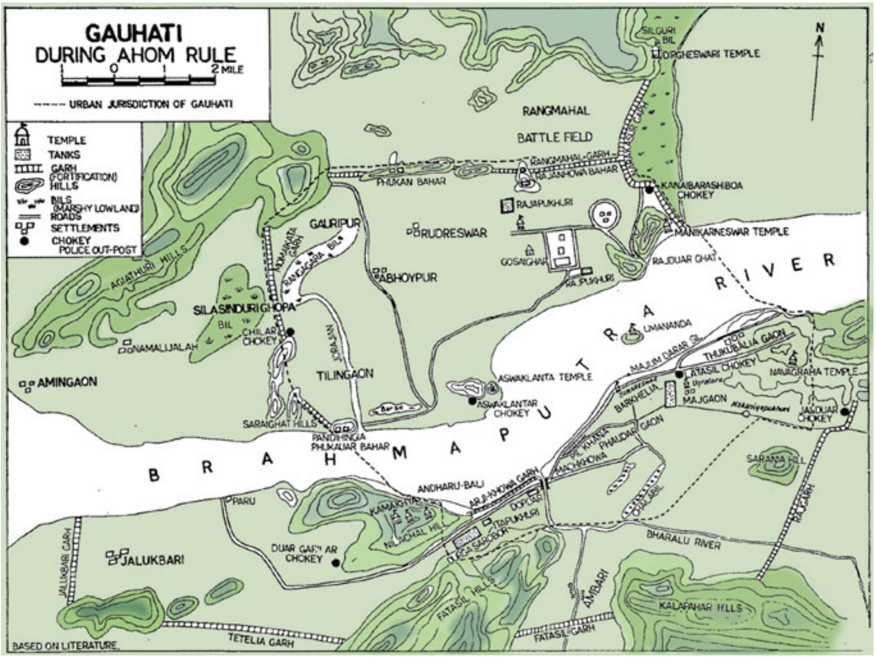

Fig. 27.1 Medieval period—thirteenth to eighteenth century AD *Source* Gauhati: A study in Urban Morphology, Thesis, Utkal University

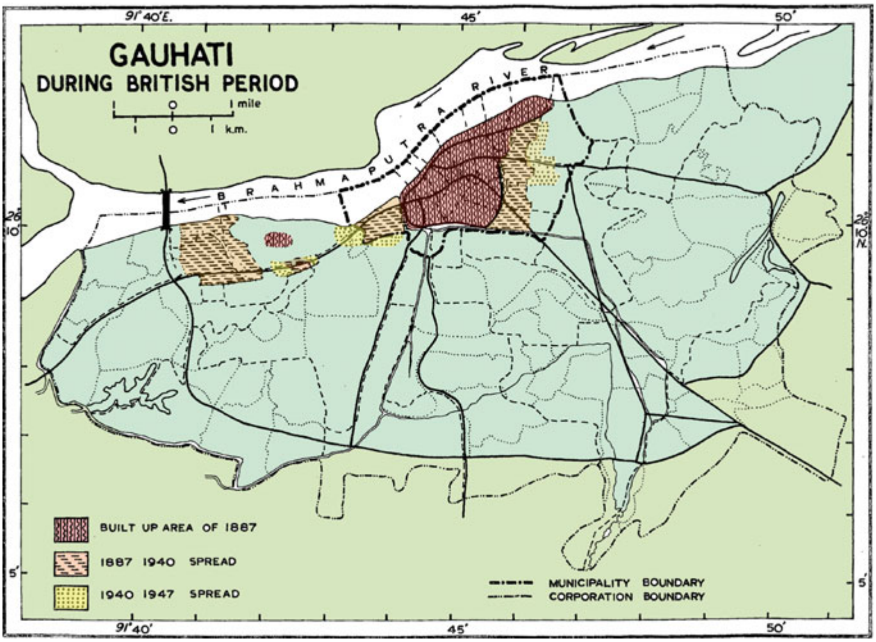

Fig. 27.2 Colonial period—nineteenth to mid-twentieth century AD *Source* Gauhati: A study in Urban Morphology, Thesis, Utkal University

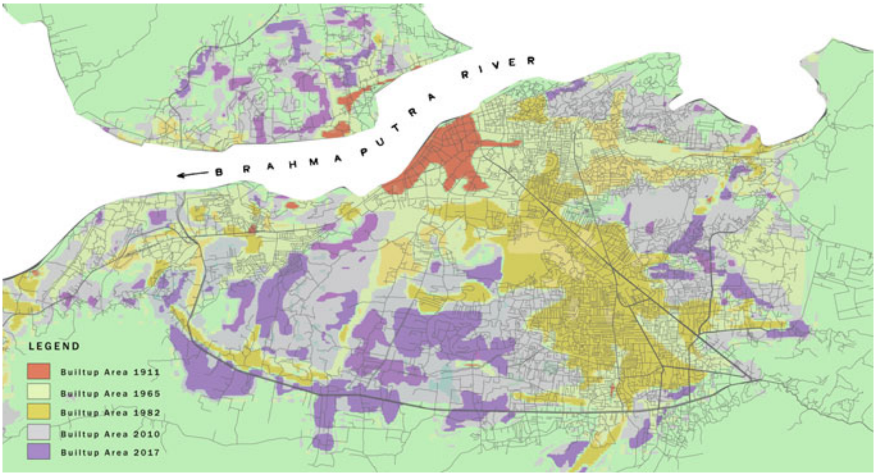

Fig. 27.3 Modern period—mid-twentieth century AD to present times. *Source* Yadav and Barua, J Ecosys Ecograph 2016)

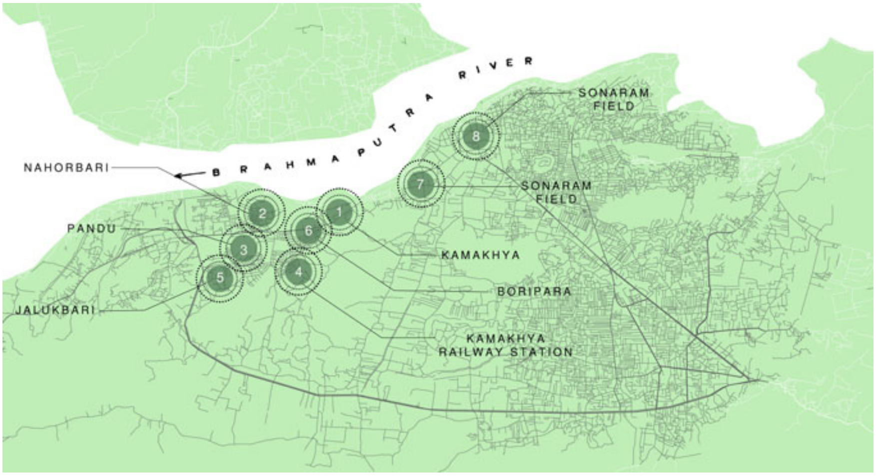

Fig. 27.4 Ambubachi Mela, 2017 hot spots. *Source* Author

27.4 Ancillary Systems: Rituals and Celebrations of Space

Urban spectacles/festivals contribute to a heterogeneous image of a city in this era of globalisation. Urban spaces transform their symbolic global image and merge with the celebratory imagery of age-old myths, rituals, culture, history and people. The majority of the academic literature on contemporary urban festivals is devoted to the denotative study of festivals with little attention to connotative experience of the festivalgoers [15]. Harcup [16] argues that festivals support the redefinition, rediscovery and expansion of urban social life and imparts meanings to a place through specific appropriations of urban spaces. Despite the ongoing critical evaluation of festivals as agents for wider political and economic gains, these temporal events provide opportunities for social engagement through experiences in festival spaces and can be key aspects to enrich identity and build social bonds [17]. Urban festivals will be explored as a tool in this paper to understand how they function as informal arenas wherein social identities metamorphoses in the context of the changing social and spatial organisation of the city [15]. In the last few decades, festivals have become a popular instrument to create a sense of distinctiveness and unique identity of cities around the globe. Researchers have determined that festivals not only help a city to preserve its local culture and history, but also enable it stand out as a tourist destination, thus contributing to the urban economy in urban areas [18]. Urban festivals are celebrated in existing urban spaces which are part of the formal built structure of the city. Some of the spaces may be used temporarily as sites for these festivals where time and space are always confined. By compressing people and activities within these urban spaces, festivals in urban areas can lead to heightened sensory and emotional experiences. This can bring out some interesting observations on how these urban festival spaces transform with time and context. Stevens et al. [17] in their study on street carnivals and art exhibitions reiterate that local social space is not a static reality, but constantly evolves through spatialised performances, encounters and discourse between actors. Rituals are repetitive processes through time, space, actors and acts in the same space at the same time. They are instrumental in merging the present and past traditions within the urban fabric. These social occasions are manifested through storytelling, selective memory and set behaviours associated with a myth of the given place. They thus contribute to the revival of collective memory or celebration of collective memory beyond the functional level [19].

27.4.1 Ambubachi Mela: Origin, Symbolism and Narratives

Ambubachi Mela is a week-long festival held around the middle of June in the Kamakhya Temple Complex of Guwahati. Every year during the Assamese month of Aahara (middle of June), the hills of Nilachal on which the Kamakhya temple stands transform into a sea of humanity as thousands of devotees cutting across geographical spectrum of India throng the abode of mother Goddess Kamakhya to celebrate her annual menstrual cycle. For close to a fort night, the hills teem with people from different hues, seeking salvation in the creative and nurturing power of Mother Earth beautifully symbolised by nature's fury witnessed during this period of monsoons. Being a unique amassment of a multitude of people, the mega event of Ambubachi Mela has turned out to be one of the major events in the eastern part of India. This annual Ambubachi Mela is also known as 'Mahakumbh of the East' which draws lakhs of devotees—tourists, sadhus and tantrics—from all over the world.

During the Ambubachi Mela in Guwahati, the doors of the Kamakhya Temple remain closed for the entire duration of three days as it is believed that the Mother Earth becomes unclean for those days. During this time, any kind of farming work is not taken on. Daily worships and other religious performances are also stopped during the Ambubachi Mela of Guwahati in Assam. After the completion of three days, the doors of the Kamakhya Temple are reopened. But the doors of the temple are reopened only after Devi Kamakhya is bathed and the other rituals are executed. It is then believed that the Mother Earth has retrieved her purity. This is purely a ritual of the Tantrik cult. On the fourth day, the devotees of the Goddess are allowed to enter the temple for worshipping Devi Kamakhya. The Prasad is distributed on the fourth day in two forms—Angodak and Angabastra. Angodak literally means the fluid part of the body, whereas Angabastra means the cloth covering the body.

As regards the worship of Goddess Kamakhya, there are various narratives within history and religious texts. The explanation given by the Kalika Purana states that it started with the occupation of the Nilachal Hill, where Goddess Kamakhya resided by Narakasura. The Kalika Purana mentions the legend of unrequited love Narakasura had towards Goddess Kamkhya. The Goddess relented to Narakasura's repeated approaches for marriage on the condition that a temple be erected in her honour on Nilachil Hill, while excavating a tank over the hill and the construction of four roads leading from the plain to the hill, all in the course of a night. When the demon, Narkasura had almost accomplished the task, the Goddess caused a cock to crow before dawn proclaiming that the night had passed and hence the demon had failed in his task. Whereas noted historian R. M. Nath gives an explanation to this effect that presence of Red Laemetite caused the reddish tinge of water flowing out from a natural spring during monsoons which represented the menstrual cycle of the Goddess. At the point where the water oozed out from the rock, there was a natural fissure conical in shape and reddish pink in colour resembling a female genital organ. This further strengthened the belief that Mother Earth menstruated through this fissure at the peak time of cultivation. The place was therefore called Ka-ma-kha, which later on was renamed as Kamakhya by the Hindus. The Kalika Purana gives an etymology of the name of Kamakhya as the combination of two words *kama* and *akhya*, meaning whose epithet is *kama* [20]. The narratives to the origin of the worship of Kamakhya are as manifold as the various forms she acquires. To this effect, Dr. B. K. Kakoti comments 'The Kalika Purana harmonises the amorous conception of the goddess with the dreaded goddess Kali by presenting the picture of a goddess in threefold aspects assumed in different moods. In her amorous mood the goddess holds a yellow garland in her hand and stands on a white corpse. When her amour is gone she takes up the sword and stands on a red lotus placed on a bare white corpse. In her mood of benevolence (Kamada) she mounts upon a lion so she assumes one form or another according to her whims (Kamarupini)' [21].

With the advancement of communication facilities, there has been a huge influx of pilgrims and visitors to Ambubachi Mela. In the year 2016, this Mela witnessed a footfall of around 15 lakhs devotees and has been heralded as the largest festival in the entire north-east of India. Due to the increase in the number of devotees, additional facilities had to be arranged which could not be accommodated in the temple premises itself. Since 2012, various urban spaces in the Guwahati City have been earmarked to help cope with this situation. The Kamrup Metro Deputy Commissioner along with the Tourism Department has been actively involved in the promotion and functioning of this Mela.

The case study of the yearly religious festival of Ambubachi in Guwahati has its own particular narratives, space and spatial movement (rituals), that creates a visual imagery inscribed in the urban fabric. This study would however focus on urban semantics through the study of this annual festival in Guwahati and pertain to analyse the role of festivals as temporal marker, spatial marker, narrative fortifier and visual identifier. This study has its limitations as it cannot be the yardstick to explore the full scope of visual culture of urban festivals. It can nevertheless provide a basic framework for further study and discourse on these aspects.

27.4.2 Morphology of Festival: Temporal Marker, Spatial Marker, Narrative Fortifier and Visual Identifier

Semiotics as a discourse analyses the processes of constructing and understanding meanings through the study of signs based on the denotative correlation with the cultural values of a given society. Urban semiotics, with its roots in social semiotics, is the semiotic approach to urban studies which considers social connotations in addition to the phenomenological analysis and denotative meanings of signs. As such, urban semiotics focuses on the tangible and intangible cultural products in urban form. Many scholars such as Barthes, Greimas, Jachna, Rose-Redwood et al. have produced seminal work through semiotic models in empirical studies of the urban landscape to highlight the construction of meaning in urban environments.

In the case of the Ambubachi Mela in the historic core of Kamakhya, a multitude of interrelations between people, rituals, myths and stories conjoin to create the urban imagery of the urban form and the ritual. Van Gennep [22] addresses the dimension of time through the division of rituals into three stages—the 'preliminal', 'liminal' and 'post-liminal' where the ritual time occurs during the 'liminal' stage. The 'preliminal' stage demarcates the spiritual time in space from the everyday mundane space–time and commences before the start of the festival of Ambubachi. This period can extend to a year as well, with the arrival of the devotees from various parts of the globe and the celebratory measures undertaken by the temple authorities apart from the organisational measures. The 'liminal' period commences with the closing of the door of the temple for three days to all devotees to preserve the sanctity of the ritual of menstruation of the Goddess. On the fourth day, the idol of the Goddess is bathed and is taken out in a circumambulatory procession around the temple. The doors of the temple are opened after this ritual. The 'post-liminal' period can be identified by the desanctifying of the religious urban spaces, the removal of the decorative elements from the celebration spaces and the return of the devotees. This can be denoted as a temporal marker of the urban spectacle as it culminates in the temporal erasure of memory from the urban fabric and the narratives associated with this festival.

Festivals are inseparable from their spatial settings. Neither can they be separated from the participants that occupy those spaces. There is an intuitive relationship between festivals, their spatial settings and the participants. The site of the Ambubachi Mela festival is the Kamakhya temple. During the festival, the site of the festival transforms into a space for celebration. This space inscribed in myths, stories, rituals and collective memory is easily demarcated from the everyday spaces surrounding it. Having defined edges, Ambubachi can be separated in space or time from the common terrain. The road leading up to the Kamakhya Temple has an entrance gate which clearly demarcates and designates it from the urban fabric of the city. It creates a territory which allows people to separate themselves emotionally from everyday life and give themselves over to the festival. Thus, the urban space of the Ambubachi festival is a spatial marker with a clear boundary during the days of the festival.

The festival of Ambubachi is rich in its narrative of various myths, stories about the Goddess Kamakhya, the origin of Kamakhya which finds mention in various mythological texts. As these stories are repeated cyclically over the years, they are passed down into generations since the time of its origin and have thus merged with the collective memory of the people and the space. Festivals thus act as narrative fortifier with a strong foothold in the past, present and the future.

As Kamakhya Temple prepares for the Ambubachi festival, the visual imagery of the temple as the site of pilgrimage ground is experienced through the throngs of ascetics, trantiks and devotees, decorations and the general air of festivity surrounding it. The senses of visual are stimulated through the feel of movement through space, the sight of costumes and colour, decorations of the temple, accompanied by various smells blended by the imagination into an unusual experience. During Ambubachi Mela, the visual setting of the festivals transports one to a surreal experience. As emotions are heightened, these urban spaces gain special importance as sites for collective memory and attachment.

27.5 Conclusion: Semiology and the Urban

Urban festivals as temporal events can combine the two dimensions of narrative: the temporal sequence of events and the tangible spatial setting that it is inscribed in. The yearly festival of Ambubachi Mela creates a powerful urban spectacle associated with history, myths, people and narratives. This can provide the basis for understanding age-old rituals and traditions in a modern setting. This unique narrative of recurring collective memory and consciousness contributes to the socio-spatial identity of cities. In a globalised world, the festival of Ambubachi is a palimpsest of urban imagery, collective memory that transforms the urban landscape from a mundane everyday space to a kinetic space where multifarious urban identity finds expression. During these festivals, urban spaces create a temporal experience which transcends time and space as the senses are heightened due to the visual and spatial settings. These events thus invoke place memories that percolate down generations which impart the distinct identities to urban places.

This research paper pertains to bring to light that ancillary systems inscribed in narratives in space create a bridge that transforms urban form from its empirical stance of the physical to the realm of symbolic connected to identity and place attachment. In a growing complex world of multifarious elements at play, urban environments are becoming increasingly more difficult to read. This paper hence highlights the imperative need for interdisciplinary research and study that can accommodate these various contexts in account to provide a better understanding of our surroundings. The paper aims to conclude that urban form when read and analysed as a palimpsest where various narratives are at interplay acts as a marker contributing to notions of place attachment and place identity, thereby expanding the definition of urban environments above and beyond the traditional norms of understanding urban environments by highlighting the role that ancillary systems such as festivals play in the current globalised context.

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Chapter 28
Reassessing User-Friendliness of Evolving Graphical Interface Design from Social Perspective

Abhinav Basak and Shatarupa T. Roy

Abstract The saturation of software in industries is too obvious a fact to be mentioned. Nearly every business in the world is dependent upon software industry. Organizations are keen toward enhancing the user experience of their software interface. Earlier, the software applications were command line driven where users had to remember and type commands to which system performed associated actions. But nowadays, virtually all applications are operated through graphical user interface (GUI). Users just drag mouse, click buttons, and apply combinations of keystrokes to accomplish a task. This is how GUIs have made the software friendlier to the users. The aim of the research is to find out how users become accustomed to features over time, how they interpret the meaning associated to the symbols in different contexts, and how semiotics plays a role here to provide affordance to the users, thereby helping them familiarize with the interface quickly.

28.1 Introduction

Semiotics is the science of signs. It is about how signs and symbols gain meaning. In the context of design, it aims to understand the form of a sign or a symbol or a product or an interface, the meaning and function that the user derives from it. It helps a great deal in understanding the users' mindset and approach toward different elements presented to them in a product, sign, or an interface. The field of semiotics emerged from studies in linguistics and aesthetics. In linguistics, semiotic studies emerged from an understanding of how words, signs, symbols, sounds, and received meaning in the context of the words around them. According to Saussure

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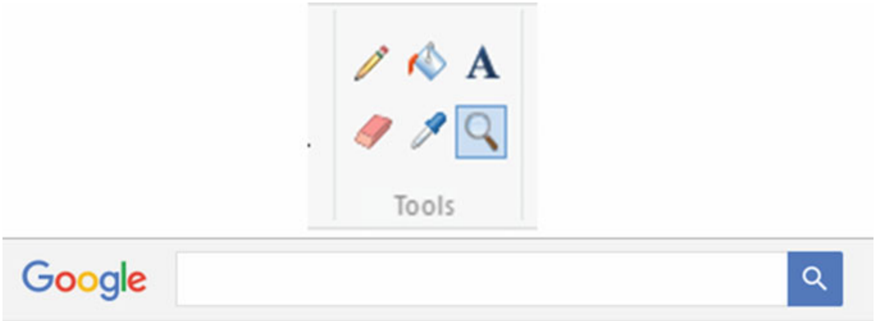


Fig. 28.1 One symbol representing two different functionalities at different instances

[1, 2], semiotics is the study of the relationship between a concept (e.g., a clickable button on the screen) and the form that it was represented in (maybe a blue rectangle with text in it). Saussure believed that elements of the form do not have a meaning of their own, but they derive meaning from the contrast with the elements around them. If we try to understand this statement in the context of graphical user interface, then we can say that the components such as icons, pointers, text, and layout do not hold any meaning individually, but they attain meaning and function when they are placed relative to the elements around them. For example, if an icon of a magnifying glass is provided in a toolbar along with other icons, it may denote symbol of magnifying glass to zoom into a particular area of the screen as any other image would be, but when placed next to a text box it represents itself as a symbol for find or search action (as in the case of popular search engine Google) (Fig. 28.1). Thus, in interface design, the meaning of symbols changes as per its context and the user adapts himself according to the layout of the interface designed by the software manufacturers.

Semantics is the science of exploring and researching meanings of languages. As semantics is the study of the meaning of words, similarly visual semantics is the study of the images and their meanings. The appearance of the visual product, i.e., the image, such as its form, style, color, size, function, and context, is widely recognized concerns of visual semantics as they form the meaning and concept that image seeks to convey. The information presented visually is processed differently from information presented in the textual form. If we consider the visual elements in a computer interface, Just as we are hardly pleased to see a human face without a skin, for ordinary computer users, understanding does not involve wires, chips, arithmetic units and electronic rays that activate images on the screen [3]. Typing and reading are not same as speaking, watching, or listening [4], and information presented from other channels is influenced by visual information, which is processed first because processing behaviors or text-based information requires more cognitive resources than processing visual information [5].

28.2 Description and Analysis

Following are a few good examples of GUI elements to analyze how the mental model of a user is shaped as he/she accesses the features and familiarizes with it with the evolving technology.

Earliest computer interfaces were command based and users had to remember commands to perform a certain task associated with the command. To overcome this problem/to reduce the cognitive load involved in command line interface, graphical user interface (GUI) was developed for the first time by Xerox in Palo Alto Research Center. The graphical user interface worked on the concept of WIMP which stands for windows, icon, menus, and pointer, where

- a window is a program that displays the current actions performed by the user;
- an icon is a graphical representation of a program or application. It acts as an origination point to initiate a program or task;
- a menu is generally a text-based selection system that executes tasks or programs based on the selected text;
- a pointer is a symbol to point and select other graphical elements in order to execute them.

This type of interface improves human–computer interactions by encouraging natural behavior while interacting with computers as well as improves user-friendliness for all user categories by replacing the hard to learn command lines and procedures with visually similar imageries so that the computer user can easily identify the functionality of the provided image by recognizing it as a representative of related object.

The first mouse pointer which was developed by Xerox for its 8010 system was an arrow placed vertically on the screen (Fig. 28.2).

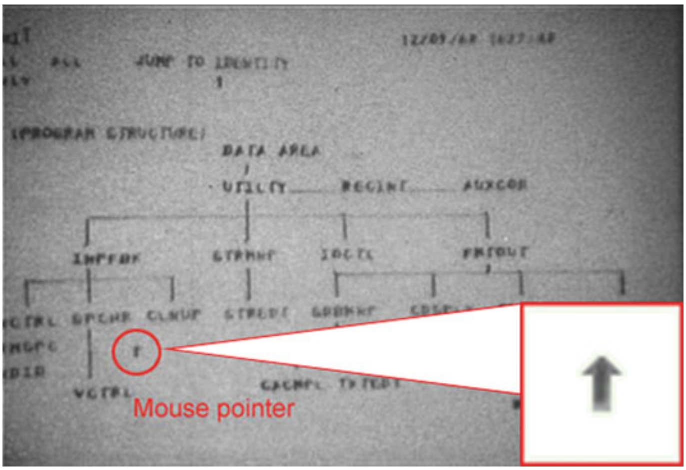


Fig. 28.2 Vertical mouse pointer [6]

Arrowhead was encouraged in the mouse pointer so that it could assist the movement of eyes toward the required position on the screen. Arrow is a strong symbolic representation for guiding the eye to point the visual element. It is long being used as a tool to effectively explaining directions on maps. And as the form of the arrowhead was reduced to a basic triangular shape, it conveyed the meanings better [7]. To understand this, references from fine arts have been taken. As an artwork could not come with additional instructions, artists throughout ages have explored possibilities of hidden arrow formations to keep the main focal point fixed and secondary accents in visual interface. A condition that seldom uses sign and its association may mislead the user and force tasks leading to inconvenience and discomfort. Figure 28.3 shows the famous painting by artist David Hockney titled "Mr. and Mrs. Clark and Percy." Here, the arrowhead is deliberately formed with the help of one corner of the table which brings the focus onto the subject matter of the painting. Similarly, in the painting titled "Fair Rosamund" by artist John William Waterhouse (Fig. 28.4), the arrowhead formed by the edge of the portrait in the painting shifts the focus of the viewer toward the character peeping out of curtains. "The Little Street" is another example which depicts anticipatory art movement in Vermeer's painting (Fig. 28.5). Here again, a diagonal line is intentionally created to assist the focus of the viewer to observe the depth and make the character inside the house look more prominent.

But due to the low resolution of the screen and uneven size of the pixels those days, it was sometimes difficult to locate the vertical pointer in the presence of text on the screen (Fig. 28.2). So, in an attempt to reduce the number of pixelated edges on low-resolution screens and to make the mouse pointer recognizable, it was slightly tilted toward left and the size of the arrowhead was increased (Fig. 28.6). The tilted pointer was introduced for the first time in Xerox Star system 1987. It

Fig. 28.3 Mr. and Mrs. Clark and Percy by David Hockney [8]

Fig. 28.4 Fair Rosamund by J. W. Waterhouse [9]

was found that a tilted pointer is easy to be located among the vertical lines on the screen and does not completely hide the text behind it (Fig. 28.7). Since then it has been a symbol for pointing in interfaces even when the display resolutions have improved and there is no good reason for the mouse pointer to be tilted. Adding to it, with the advent of touchscreen devices such as smartphones and tablets, a pointer is no longer required as a medium of interaction between the user and the interface as pointing can be directly achieved with the fingertip.

The icons were carefully designed for Apple Lisa computer (Fig. 28.8). For example, trash resembled real-life trash can. Similarly, on inserting a floppy disk, an icon of a floppy disk used to appear on the screen so that the users can quickly understand the meaning associated with each icon.

The command symbol which is used for accessing the shortcuts is considered one of an essential symbol of Apple computer till date and would always retain its symbolic value in the future (Fig. 28.9). There is a story behind the design of the Apple command symbol.

When Apple released its Lisa computer, the shortcut keystrokes had to be used along with a button denoted by apple symbol (Fig. 28.10). Given the low resolution of the screen those days, the apple symbol was not clearly recognizable and Apple

Fig. 28.5 The Little Street by Johannes Vermeer [10]

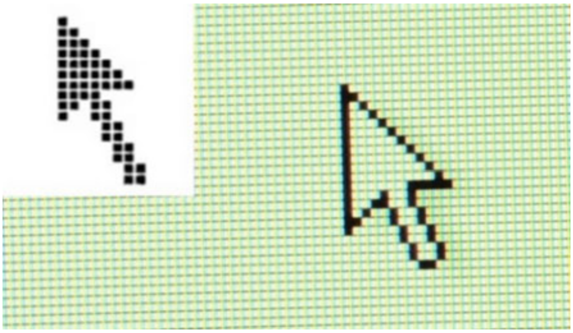


Fig. 28.6 Tilted mouse pointer [6]

co-founder and CEO—Steve Jobs—had a concern that there were too many "apples" on the screen [12].

Graphic designer Susan Kare was responsible for designing a new symbol to replace the existing apple symbol. She came up with a symbol which already existed [12]. This symbol is actually used in street signs to indicate "point of interest or attraction" in Scandinavian countries (Fig. 28.11). Kare also one step further to uncover what the symbol actually represents. She discovered that the symbol is inspired by the ruins of a castle in Borgholm, Sweden [13] which appears

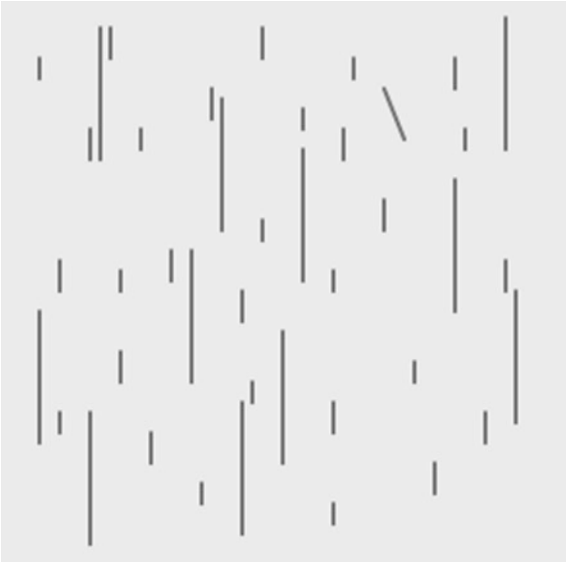


Fig. 28.7 Locating tilted pointer against vertical segments [11]

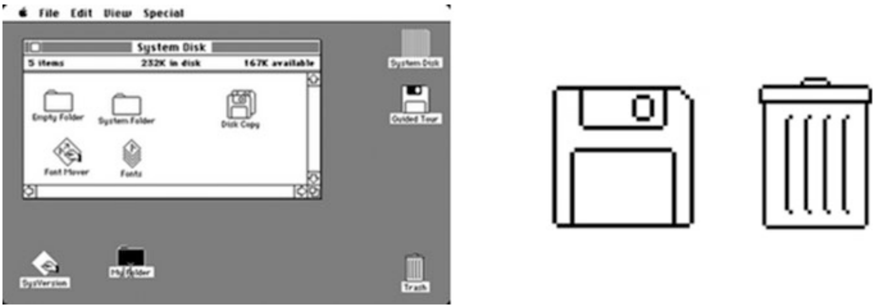


Fig. 28.8 Apple Lisa icons

as a symbol for point of interest when seen from above as shown in Fig. 28.12. The symbol was so simplistic that it could be easily recognized even in low resolution of the screen. The command symbol is still used in the current operating system of Apple (Fig. 28.13) and is also a part of the keyboard in Apple computers (Fig. 28.9).

Nevertheless, symbols as used in GUI, sometimes convey a false pragmatic meaning. One example is Apple system error message being represented with a bomb icon (Fig. 28.14). This resulted in people calling Apple being frightened about the fact that their computer would blow up.

Fig. 28.9 Command symbol on Apple keyboard

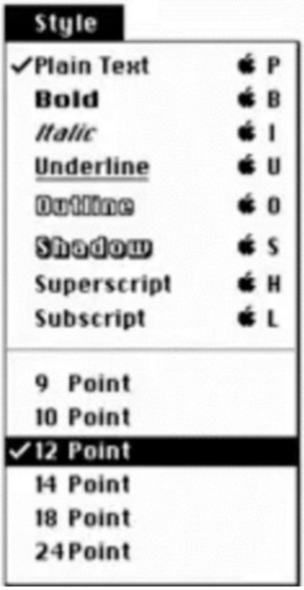


Fig. 28.10 Associated Apple symbols for shortcut keystrokes [12]

A couple of experiments have been conducted to validate the problems led by visual ambiguities in icons as well as understanding the meaningfulness in the icons, and the results are mentioned precisely to justify the relevance of the experiments. In the first experiment, the “Windows magnifier” icon (Fig. 28.15) was shown to 30 participants and the task provided was to identify the icon. But 27 out of 30 participants recognized it as the icon for search program instead. For the second experiment, a set of Windows system icons (Fig. 28.16) were shown to these participants. These icons are from a latest version of Windows operating system, i.e., Windows 10. The operating system provides an index number to all these icons; however, the identity and purpose of few of the icons are unspecified.

Fig. 28.11 Point of attraction symbol [13]

Fig. 28.12 Borgholm Castle, Sweden [13]

Unfortunately, the participants as well as the author were unable to make meaning out of the icons displayed.

When the computer started getting sold commercially as a mass market commodity to general public, a huge effort was made to improve the user-friendliness of the interface so that it could be easily understood and accessed by all users. Therefore, the components of the interface were explained as metaphors of real-world objects so that the users could relate and understand the meaning and functionality of the component. One example of metaphorical representation is Magic Desk I interface (Fig. 28.18), which had a visual environment of an actual desktop so that one could recognize the components of the system by relating the items to real-life objects (Fig. 28.17). The items present on the workbench could be accessed using the mouse pointer which was replaced by a hand with a fingertip working as a mouse pointer. The cabinets represented disk drives, whereas the

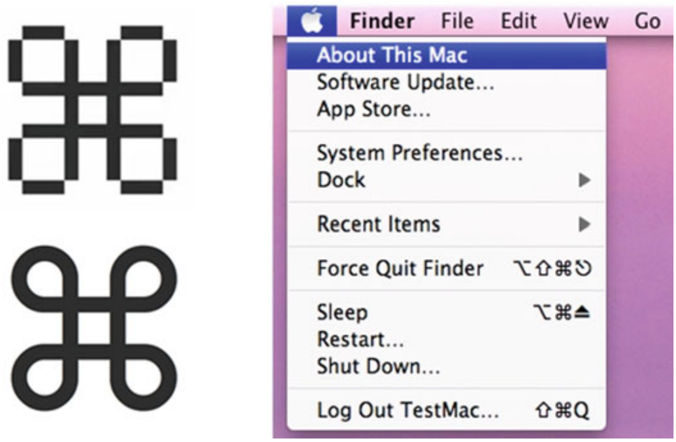


Fig. 28.13 Apple command icon

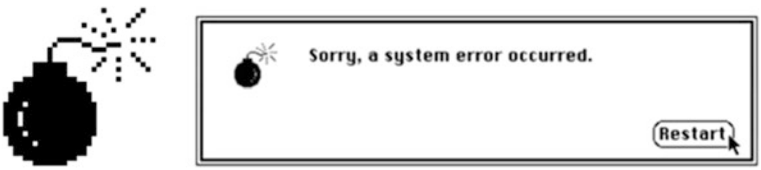


Fig. 28.14 System error message in Apple's Macintosh system [12]

drawers represented the directories. The files contained in each directory could be seen by clicking on these drawers. Typewriter represented text editor. To create a text document, one had to click the typewriter icon, and as soon as typing is finished, an icon representing a sheet of paper appears on the desk. Documents created could be deleted by selecting and dragging them to the trashcan as shown in Fig. 28.18.

Fig. 28.15 Windows magnifier icon

Fig. 28.16 Selected Windows system icons

Fig. 28.17 Real-world desktop [14]

Fig. 28.18 Metaphorical representation of desktop in Magic Desk I interface [15]

However, over the passage of time, the term “desktop” has become so associated with the computer world that on hearing the word “desktop” today, and one recalls it as computer desktop first instead of a real-world tabletop.

90’s operating systems had a metaphorical cursor states to represent waiting or busy state of the system. Windows operating system used “hourglass” to represent

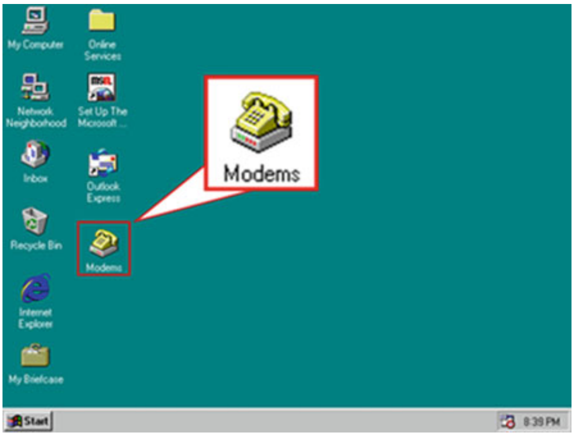
Fig. 28.19 90's "busy state" cursors [16]

the busy state of the system, whereas Apple operating system used "wristwatch" for the same purpose (Fig. 28.19). The hourglass cursor has now been replaced with a rotating ring cursor in Windows, and the wristwatch cursor of Apple computer is replaced with symbol known as "spinning pinwheel of death" (Fig. 28.20). This is due to the fact that the processing time of the computers has decreased drastically over time, and also, users do not require the help of metaphors to understand that the system is in a busy state. This is one of the perfect examples of users getting accustomed to the GUI as provided by the operating system manufacturer.

Even so, the imagery of the physical object as represented in GUI should evolve hand in hand with the technological evolution of the object; otherwise, the user will

Fig. 28.20 Modern-day "busy state" cursors

Fig. 28.21 Windows 95 "modem" icon



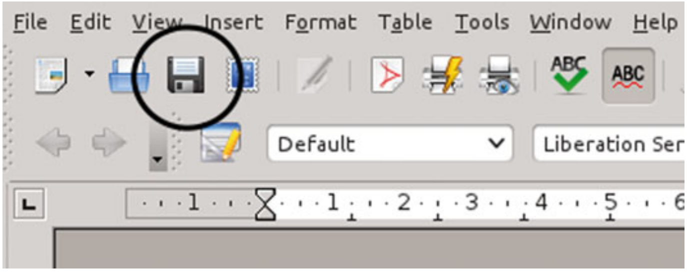


Fig. 28.22 Floppy symbol represents “save” functionality

Fig. 28.23 Telephone receiver symbol used for representing dial and reject functionality

fail to relate it to his current mental model of the object. For example, in Fig. 28.21, the “modem” is represented by a dial-up modem of the 1990s. And if this icon is shown to users now, especially to ones who have not used a dial-up modem, a large number would not be able to recognize the image as their understanding of modem is generally a USB modem.

The extinction of the use of floppy disks has increased the use of the floppy icon to represent “save” function so much so that it is no longer recognized as a representation for secondary storage as shown in Fig. 28.22.

Similarly, the dial and reject function in a communication application is still symbolically represented with receiver icon of the old telephone which is no longer in use (Fig. 28.23). People who are unfamiliar with the telephone receiver have started recognizing the symbols as an element of the interface rather than relating it with a telephone receiver.

28.3 Observations and Conclusion

- Initially, the components of GUI have to be explained to the user with the help of metaphors so that they could relate the interface with real-world objects to understand its function; but as they become familiar with the interface, they no longer require the help of metaphors to understand the meaning and functionality of the component.
- False pragmatics may lead to ambiguities in interpreting the actual meaning while accessing the user interface as in the case of “bomb” icon used by Apple for representing system error. This is further supported by experiment 1.
- Same icon may have a different meaning depending on the context of the environment where it is placed. But still user makes no mistake in understanding its functionality according to the context.
- Icon image evolves/should evolve with technological evolution since the older icon loses its meaning and is no longer recognizable in the current paradigm.
- On the other hand, few metaphoric icons may still retain its meaning even when the real-world object from which the icon is derived becomes extinct, e.g., telephone receiver icon. Few icons continue to survive with a different meaning than that which was originally introduced, e.g., floppy disk icon.
- Few symbols achieve iconic meaning depending on the functionality that it provides to the user, e.g., mouse pointer, Apple command symbol.

28.4 Future Scopes

The study directs to the field of inclusive design developments that targets a wider range of users. The flexibility that is offered by customization plays two major roles in the design endeavor. Firstly, by letting the user overcome difficulties caused by physical uniqueness and secondly by treating the target user with due empathy that is derived in an advanced/modern interface design. The designer is instrumental here to tell the users that there is no room for discomfort in the receiving end. Instead of adjusting with the interface, they may expect the interface to adjust and alter.

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Chapter 29
Semiotic Analysis: A Study to Identify the Design Elements of Namghar in Assam

Charu Monga and Amarendra Kumar Das

Abstract This paper is regarding the application of visual ethnographic research to facilitate preservation of the cultural identity of structures of Namghar, which is an important sociocultural institution. Design elements of Namghar are essential and symbolic for binding the entire community especially belonging to various areas of Assam. However, rapid urbanization and changing lifestyle have led to variations in design elements of Namghar. This study on these variations in design elements will be of interest in preserving the essence and harmony among diverse communities as well as heritage of Assam. The objectives of this study are to compare variations in design elements especially semantic variations of Namghar located at different locations within Assam. Field observations of external overall structure, elements as well as interior structure were made. Similarities and differences among key vernacular architectural design elements were compared and discussed. Cultural aesthetic elements were explored with visual deconstruction of architectural elements between Namghar in various locations. It is identified and discussed with reference to semiotic analysis. Also, it is used for constructing Namghar culture in structured way. This paper seeks to arouse the issues of cultural loss of Namghar and possibility of forming, meaning as a binding design aspect among the vernacular architecture of Namghar.

29.1 Introduction

Namghar are sociocultural institutions that were introduced in Assam by the Vaishnavite Saint Srimanta Shankardeva between fifteenth and sixteenth century AD. These were introduced as a consequence of Vaishanava Bhakti movement, which initiated after inequality; suppression of lower class and intricate practices in

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Hinduism reached its peak in fifteenth century. This movement aims to bring everyone into the same level and give birth to equality. During that period, Namghar were essential structures, which are basic building blocks of Assamese society. It is not only a place of worship but also a central meeting point, where all the people discuss about the issues related to their society. Namghar also called Kirtan Ghar functions as meeting points of congregations, as well as theatre of dramatic performances like Bhaona, Raas Lila, and many others [16].

The Satra institutions are unique institutions with multidisciplinary socio-religious, cultural, art, and also architectural domain with its distinctive characteristics derived from the Bhakti movement [7]. From architectural point of view, the design of the above institution has been also influenced by various external (or foreign) tribes, which have travelled from different parts such as Bhutan, Thailand, Mongolia, and other parts of East Asia [11]. The migration of various people [4] from different neighbouring parts around Assam was taking place. Assamese culture was developed under the great dynasties of Pragjyotisha-Kamarupa, during the first millennium A.D. "*The modern name of the province, Assam, is actually of quite recent origin. It is connected with the Shan invaders who entered the Brahmaputra Valley in the beginning of the thirteenth century A.D., and who were known as Ahoms*" [5]. It is developed due to acculturation of different ethno-cultural groups under various sociopolitical systems in different periods of history [9].

29.2 Aim and Objective of the Study

The **aim** of the study is to explore various design elements in Namghar of Assam. The **objectives** are (i) To identify associated meaning in relation to design elements of Namghar, which helps in categorization of critical elements; (ii) Studying the uniqueness of Namghar and understanding its identity.

29.3 Methodology

The methodology includes mainly semiotic and connotative interpretation of data gathered during extensive field study using visual techniques as well as literature review on Namghar. Primary and secondary researches have been done, and the qualitative approach has been followed to understand the in-depth meaning of elements associated with Namghar. In addition to field survey for capturing visual data, the questionnaire was designed at multiple stages (i.e. three stages). Based on the feedback during the initial visit and discussion with experts, the questionnaire was modified. The methodology proposed by Boynton and Greenhalgh (2004) for questionnaire was adopted. The evolution of questionnaire at different stages of research had taken place. In the first stage, it was mainly a general questionnaire, which was designed based on literature review analysis. This included qualitative questionnaires for collecting different types of data from wider range of respondents (President, Vice-President; Satra Adhikari and Bhakat's) and also conducted chronological comparisons. Whereas, in second and third stages, the interview schedule (with successive qualitative and visual questionnaires) was designed based on subsequent analysis of data collected from first and second field surveys, respectively. Second set of questionnaires were designed based on the initial findings from first field visit.

The main Namghar (Barpeta), which is one of the oldest institutions most likely to be preserved, was selected for investigation with other new Namghar. Field observations were conducted using high-resolution cameras to capture exterior as well as interior elements of the Namghar. Images were compared and visually analysed to identify and compare the forms and aesthetics of key architectural (external and internal) elements of Namghar. Different forms of elements were then discussed with references from literature.

This was followed by in-depth interviews and semi-structured group discussions with several people of influential positions (such as President, Vice-President, Satra Adhikari) in Namghar shown in Fig. 29.1. Second set of questionnaire was prepared, where specific information related to design elements' details (outer gate, pillars, door, floral elements such as lotus) was enquired. After considering the input from initial interviews and focus group discussions, the questionnaire was prepared for the pilot testing. Final set of questionnaires were then used to collect data in the final field visits to each of these Namghar. The collected data from literature review analysis, field visual survey as well as questionnaires were analysed in order to unfold semiotic and connotative significance. The qualitative answers derived from the respondents were very interesting as they mentioned about the striking differences between a Temple and Namghar. Also, how there are typical design elements associated with Namghar and from where their adaptation

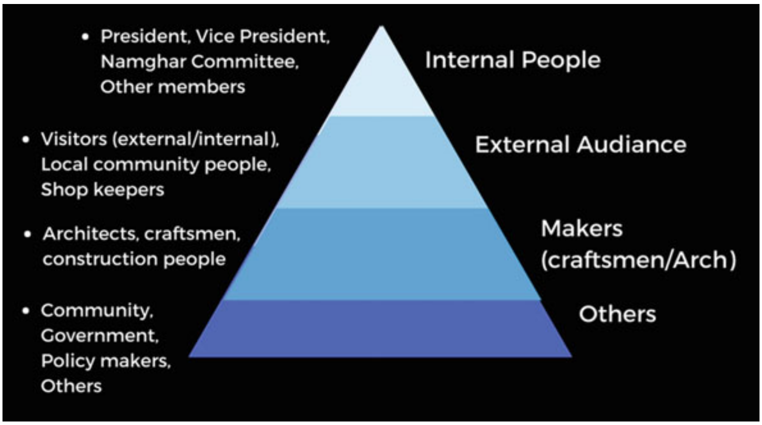

Fig. 29.1 Various stakeholders for interviews and focused group discussions

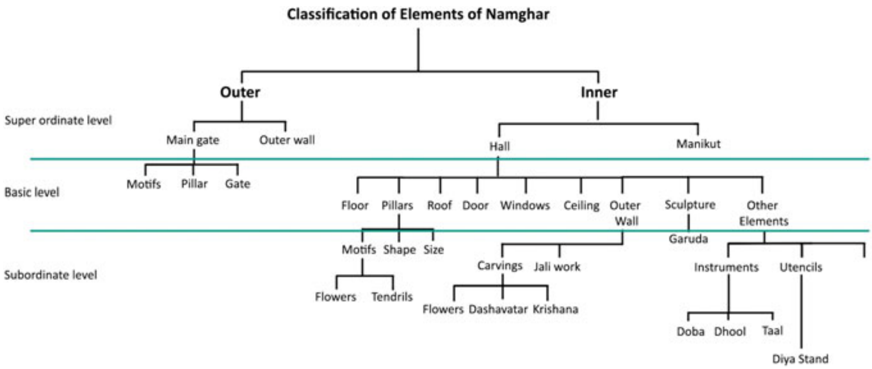

Fig. 29.2 Adopted from Categorization…Natural Language and Design [2]

has happened leading to retaining their identity. Categorization theory [1] has been identified and adopted to further segregate the collected data (Fig. 29.2).

For analysing the design elements in Namghar, semiotic approach has been adopted from Barthian's theory of visual identification. His idea is to identify the layer of meaning associated with elements connected with the visual semiotics. The first layer denotes the layer of ***Denotation***, which gives an idea about with whom and what is being represented? Here are few examples is been represented of Xorai and Gamosa.

Object	Denotation (Who/what is being represented)
	**What**: Xorai (name) **Form**: It is a metal object which is having a half cylindrical and semi-sphere on top shape **Function**: It is been used as an offering utensil or tray for prasad (devotional offering of food) and other items placed in front of the altar (Namghar) for gaining blessings of the lord and is used while performing respectful offerings
	**What**: Gamosa **Form**: A hand-woven white cloth with design woven with white and red colour thread **Function**: It is used as a gesture of respect, and it is very auspicious and represents the Assamese identity and culture

The other layer which represents its meaning is ***Connotation***, which enquires about the value and idea expressed through what is represented and through the way in which it is been represented [17].

Denotation (Who/what is being represented)	Connotation (value/idea expressed)
What: Xorai (name) Form: It is a metal object which is having a half cylindrical and semi-hemisphere on top shape	(i) It is a manufactured bell-metal article and an object of huge respect and is used as a container-medium while presenting respectful offerings (ii) It is also been used as offering utensil/ vessel or tray in which food or prasad can be offered in front of the altar (Namghar) for blessing of the God
What: Gamosa **Form**: A hand-weaved yarn white cloth with design weaved with red colour thread	(i) It represents social status (ii) It also represents an act of purification and respect

For viewers who know the language or who are already associated with Namghar, it is very easy to tell about the object or the elements associated with these Namghar elements but what other meaning the producer is expressing with the help of design of the objects has specified is something, which requires more efforts to decode the hidden meaning inside. It will be noteworthy to consider the Saussurean dyadic model of sign in Fig. 29.3.

The making of meaning and conversion of design elements in Namghar varies on these values and associations created by different components of the elements in Namghar. For a researcher, it is essential to have second-order understanding to provide appropriate sign so that viewer would be able to decode the meaning and understanding behind what is been denoted [12]. In the same way, a second-level understanding is required by the viewer to decipher the associated or symbolic meaning behind what is been characterized or represented. At this point, second-order understanding is been required in the appreciation that, when the viewer will look at the different elements of Namghar precisely on the Manikut with its literal meaning, they should be able to decode the message given by the maker (here a craftsmen) of the Manikut. In many possibilities or time, maker would present the Manikut with some sign to understand those hidden meaning. Also their meanings were suggested by society, which leads to understanding of the object (here Manikut). For example, the role of Manikut in the Namghar setting has been used to give the symbolic meaning like seven stairs represent the seven levels to reach *moksha* or to the supreme, which is God and with that representation of Vishnu avatars (symbolic characters). Hence, this approach of bringing the meaning out of the context is been used everywhere in the study to analyse the elements of Namghar and decode the meaning behind the object or image to bring out the result.

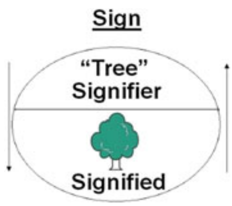

Fig. 29.3 Concept of Signifier and Signified

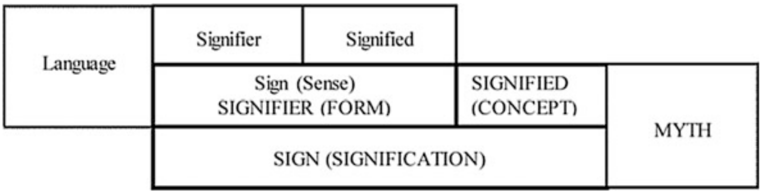

Fig. 29.4 Structural analysis (Barthes 2009, p. 205)

29.4 Structure and Meaning Making

Individual elements act as building block of an object (Xorai with Gamosa, betel nut together) where its form, placement, and dimension play an important role in communication of object matter (composition). Considering from the Barthes's visual semiotics point of view, his denotation of individual elements is an unproblematic issue. Knowing the written language ensures each viewer to understand the literal meaning of object. But the constructive meaning of the object gets generated through understanding of the message, which is hidden somewhere in the form and structure of the object (Fig. 29.4).

This does not mean that denotation is entirely up to the beholder. This also depends upon the context [17]. This could be further understood by taking examples of two objects used in Namghar.

29.5 Results and Discussion

The nature of Typicality and A-Typicality has been selected on the basis of the frequency in which respondents have selected the particular elements like entrance gates from twenty-six different Namghars, which have been given to them through visual cards followed by visual coding. Also, the selection of typical design elements has been done more precisely in the further steps towards the frequency of typical forms depicted on the gate and doors in this case study. For the card sorting analysis for typical to A-Typical rating: Here, Atvankar's method is been adapted.

(i) **From Typical to A-Typical of Main gate (Pratham Dwar)** (Fig. 29.5)

For the Namghar main gate (also called Dalam), the typical one is 10, 13, and 14 (this structure came from Ahom kingdom and it is more similar to Xorai) has been chosen in the highest category. The respondents have given many reasons for choosing these particular gates as it has many things like Udantu Singha (particular kind of flying lion, which has been the symbol of Ahom kingdom and represents a mythical creature that is used as a metaphor for showcasing the might of the Supreme Hindu deity *Lord Vishnu*). On top of the gate, respondents mentioned about the extension of Thapana in a symbolic manner, on the same symbol of

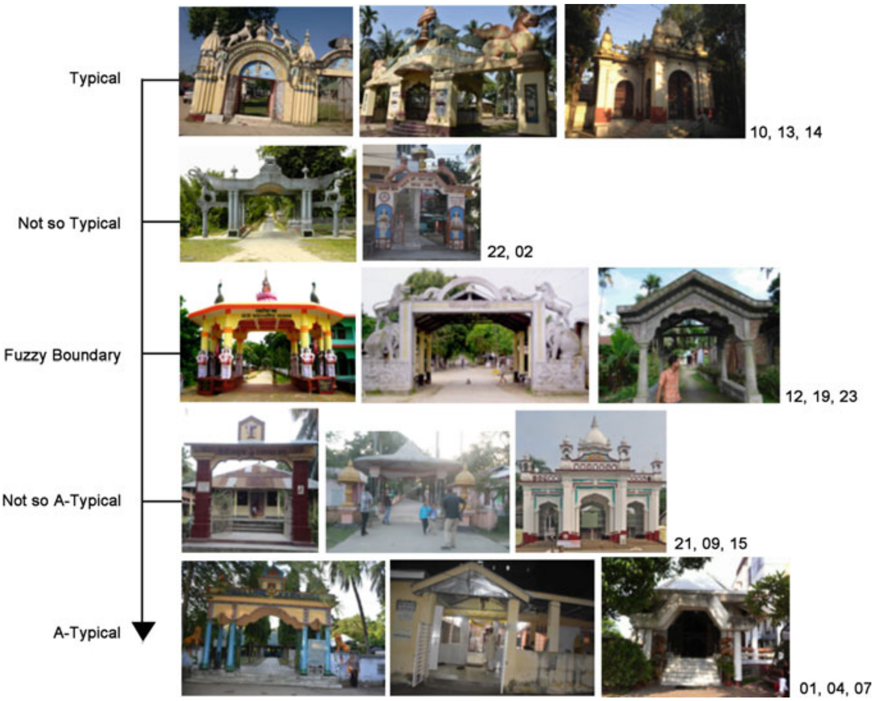

Fig. 29.5 Typical to A-Typical rating of Namghar main gate by respondents

Bhakat with Taal and Khool (musical instruments) in their hand on the gate representing welcoming of the visitors. Respondents mentioned that on the gate something in relevance to supreme (Vishnu) has to be there in form of Thapana or Vishnu avatar itself. Xorai with Bhagwat and Gamosa has been used to give respect as a symbol of Assamese culture; also, it is auspicious and has been used in the main gates. Respondents also mentioned that main gate is an extension of Thapana. Second preference has been given to gate no. 2 and 22 in which some of the elements are present like Singha (lion) and Jai Vijay, but Singha is not the exactly Udantu Singha (flying lion). Gate no. 15 looks more like Mohammedan architecture.

Summarized the findings: For the **main gate (Pratham Dwar)**, respondents have given the preference to the following and mentioned that the following things have to be present in the gate of Namghar:

(a) **Udantu Singha/Nama singa (flying lion)** denotes bhakti also called Namghar *Rokheyas,* i.e. the protectors of the Namghar. It is been believed by the people that the lions protect the Namghar. It processes extraordinary martial prowess. In the *Simhasana*, the lion is always depicted as a dominant to the elephant. It symbolizes the idea of sin being destroyed by the name of God [13]. Similar inferences can be drawn for the Singha Duar.

(b) **Bhakat with Bhor-taal and Khols** (drums with two sides): Khols are typically prepared with baked clay in Namghar and used as a musical instrument. Bhor-taal (originated from Bhutan). It is been carved on the main gate to welcome the visitors with music and hymns. The plays and songs bring the spiritual entertainment for the people.
(c) **Xorai with Bhagwat and Gamosa** representing auspicious and respect to the supreme.
(d) **Shape of dome structure**: Srimanta Shankardeva has spent good number of years in Orissa, the details of which are found in the "Oresa Barnana" section of "Kirtan Ghosa". He was greatly influenced by Hindu deity Lord Jagannath and the teachings of bhakti movement. He was inspired by architecture of the Jagannath temple, Puri and the Singha Duar (Lions gate) situated in the temple premises also the structure represents Xorai, which is a symbol of respect.
(e) There is a **crown on the top of the gate** with semi-spherical shape. This symbol is also been used in the Bhawana performance and it represents the crown.

The A-Typical ones are gate no. 1, 4, and 7 as the respondents mentioned that the main gate should not look like a house gate also there is no symbolic elements present which represents the Namghar. The lion, which has been used, is also not Udantu Singha and different Singha is been used.

(ii) **From Typical to A-Typical Main door of Namghar (Saptam Dwar)** (Fig. 29.6)

For the Namghar, main door is also called Saptam Dwar. The typical ones are door no. 10, 11, and 16. It has been chosen in the highest category. The respondents have given many reasons for choosing those particular doors as, these have many depictions of Dashavatara, which represents Vishnu and its ten primary avatars (incarnations: The Hindu God of preservation). With these representations, visitors and Bhakats instantly connects with the power of God and its presence on earth. However, most draw from the following set of figures, omitting at least one of those listed in parentheses: Matsya, Kurma Varaha, Nara Simha, Vamana, Parashurama, Rama, Krishna (Balarama) or (Buddha), and Kalki. All of them are Vishnu avatars. The stories of all Vishnu's incarnations inspire the Bhakats and visitors. Respondents also mentioned that Jai Vijay's presence on right and left side of the door is important. Also on top of the main door presence of Vaikuntha Dham (Anant Sajja), where the God or Vishnu lives has to be there as it represents the supreme of all "Vishnu" (the preserver God), which means he protects the earth from being destroyed and keeps it going and he has come to earth with its nine forms (Fig. 29.7).

Vishnu is the most famous form of Ram and Krishna. Vishnu's wife Lakshmi was the Hindu goddess of luck and fortune. Vishnu is usually shown with light blue skin and four arms. He holds a lotus, mace (Gada), conch (Shankh), and disk (Sudarshan Chakra) in each of four hands. Presence of peacock on the top of the door is a symbol of Sri Krishna. The whole main door should give the aura of Vishnu's stories/narratives. Respondents also said that traditional influence is required on the main door.

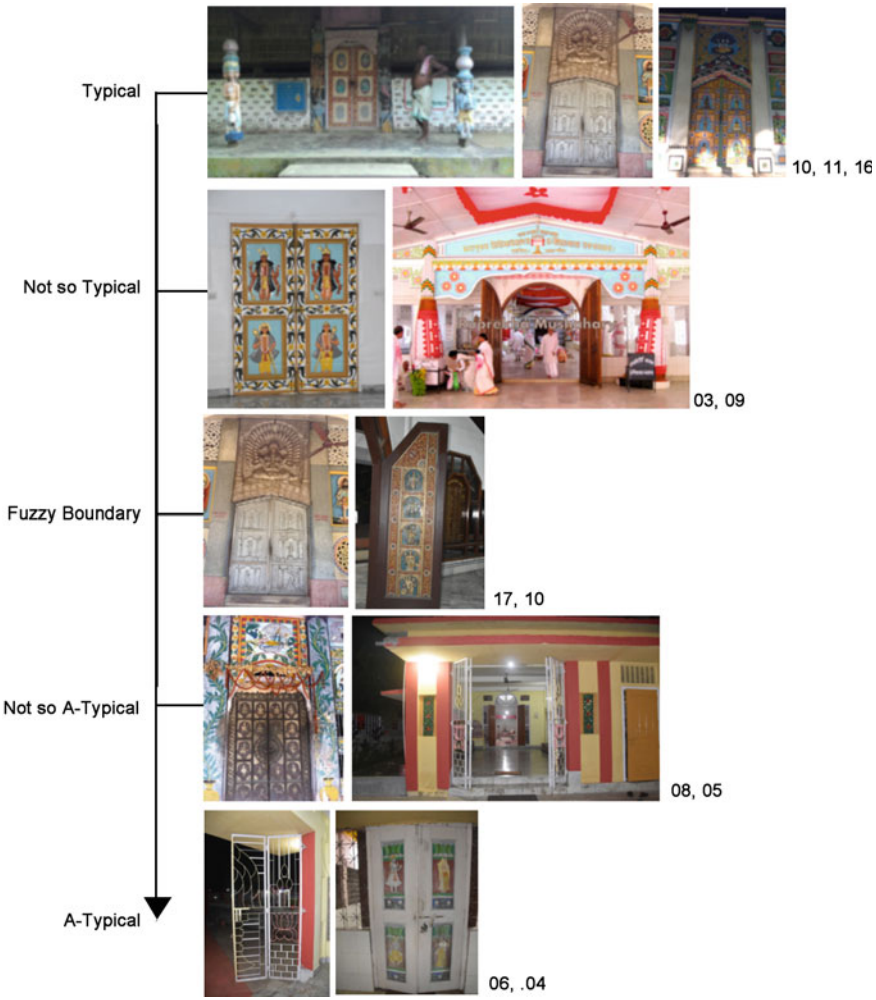

Fig. 29.6 Typical to A-Typical rating of Namghar main door by respondents

Second preference has been given to door no. 3 and 9, which again has Vishnu and Dashavatar but not in clarity as the carvings are minimal. Later, the respondents have chosen A-Typical doors as 8, 5, 6, and 4 which do not have any of the symbols or Dashavatar in any form.

For the Main door (Saptam Dwar), the respondent preferences are the following:

(a) **Dashavatar on main door:** It denotes the stories of Vishnu avatars with its incarnations. There are total ten of them, which are Matsya, Kurma, Narasimha, Bamuni, Parshuram, Hariram, Baraha, Sri Ram, Buddha, and Kalki present in

Fig. 29.7 Presence of Vaikuntha Dham (Anant Sajja) on the main door of Namghar

different ways. Respondents also said that Dashavatar did well for the earth and that has to be represented on the doors.

(b) **Vaikuntha (Unnat Sajja/Vaikuntha Dham)**: In Hinduism, Vishnu is the preserver and supreme of all. So, its position is on the top of the main door, where the main Dham should be represented. A traditional depiction is Vishnu reclining on the coils of the serpent shesha accompanied by his consort Lakshmi as he "dreams the universe into reality" [8]. It depicts the story of "Vishnupuran". It emphasizes all the religion is one and the supreme that is Vishnu and other is its avatar.

(c) **Jay Vijaya**: They were two gatekeepers of the abode of Vishnu known as Jai Vijay in the Vaikuntha (meaning *place of eternal bliss*) [6, 10].

(d) **Arch of the main door**: Polylobed arch of the pediment and the upper curve is taken from Bhawana performance.

(e) **Motifs**: It depicts the elements of nature like flowers and plants and it's taken from "Rangiyal flower" and "Ashoka flower", which had a symbolic association with Madhavdeva.

29.6 Summary and Conclusions

The complexity of the elements involved in the study was deciphered using a number of techniques viz. questionnaire, data characterization, semantic, denotation, connotation, and card sorting analysis. Mentioned above various techniques were essential in order to unfold the meaning of various elements related to social, religious, and design aspects. It was found from this study that though there are distinctive differences in physical forms of interior (pillars, praying hall, ceilings, windows, and jali works) and exterior elements (presence of creatures as guards, gate forms, and rooftop) of monuments in these Namghar, the symbolism and significance of these elements are very important and integrated in Assamese culture and in the life of the people of Assam.

The semiotic approach has been adopted, which unfolds the significance and layer of meaning and it brings out deeper understanding of the symbolic value attached to the elements in Namghar. It also gives a deep understanding towards the design dimensions because of which the identity has been adapted and survived till now. For instance, the significance of Dashavatar, Jay Vijaya, Garuda, various flowers, and animals is on different positions that depict the identity of that place or in this case stories attached with Namghar. A systematic approach to card sorting by Athavankar is been adopted for giving the collected data, a typical rating by coding the cards. Connotation method seems fit to analyse the gathered data.

The aim of the research was to analyse various elements associated with Namghar and it came out of the data analysis of main gate (Pratham Dwar) that the Udantu Singha (flying lion) has a great significance, Bhakat with Bhor-taal and khol is an important aspect of a typical Namghar to welcome people and also to evoke the bhakti among them. Xorai, Bhagwat, and Gamosa are very typical on the main gate, which shows prosperity, with this shape of dome structure and crown on the top of the gate segregates the typical Namghar with temple. On the main door of Namghar (Saptam Dwar), there is an importance of Dashavatar and Vaikuntha Dham. There has to be Jay Vijaya, who is the gatekeepers of Vishnu. There are various typical motifs, which have been derived from the data analysis like use of lotus flower associated with Vishnu and Nirmali flower associated with Madhavdeva. All these elements retained the identity associated with a typical Assamese Namghar.

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Chapter 30
Embedded Diversities: Design Explorations with the Tool of Type and Expressions

Nanki Nath

Abstract A script in India conveys a symbolic glimpse into a particular culture and the associated beliefs. There is an attractive diversity due to appearance of various such scripts. The diversity is not only in the existence of the scripts but also more critically in their visual representation. The aesthetic beauty and the traditional native identity are imbued as one harmonious unit in the multitude letterforms of any script. Indigenous 'Scripts' in India mirror the cultural essence of letterforms. Different forms of writing each script represent the origin of a script from the respective local context—where a particular language written in specific script defines the context (Nath et al. in Display Type Expressions: The cultural underpinnings of the sripts from two Royal Cities of India, 2004 [1]). This paper outlines the existence of three visual facets that are part of the representation of a script. The foremost facet is 'Language,' that provides a communicable/functional meaning to the form of the script. A language has a structure, syntax, and a cultural basis that are associated with the style/form of a particular script. The second facet consists of 'Tools or Techniques of production,' that provide the mechanics of letter structure, its construction, design, and style. The third facet consists of 'Semantics (Expressions) and meaning based applications,' that give a provision of a range of applications from unilingual to multi-lingual forms of visual display. The explorations of expressions of various local scripts and their type styles by design students showcase a range of functional meanings, cultural meanings and tool influenced meanings that nuance the compositions to a new level of aesthetics. The present paper brings forth the trifold visual approach from 'Language' to 'Tools or Techniques of production' to the final type forms that communicate semantics in the context of meaning-based communication aims. The methodology provides a scientific lens to craft the design process for better designs with type and their expressions. In conclusion, a conceptual approach in the form of an open framework has been discussed. This framework is envisioned to act as a scientific frame of reference to understand the design applications of scripts, languages, tools, and techniques, type expressions, etc.

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30.1 Introduction

Ban Comic Sans' Manifesto strongly asserts that, 'Type is a voice; its very qualities and characteristics communicate to readers a meaning beyond mere syntax' [2]. And, this type stands in affirmation—with the support of a language written in a certain script. Goes without saying, a language has its seed in the soil of a specific culture. Different languages (exhibiting a range of cultural ethos) have been living sources of continuous inspiration and motivation to develop meaningful forms in typography. History is full with revolutions in the forms as part of the individual scripts (in context of type design), as well as discoveries of new and better modes of typographic expressions with time (in context of diversity, type and expression tool).

People's Linguistic Survey of India under the supervision of Ganesh Devy (since 2010) identified 860 distinct languages in India. The Constitution of India does not give any language the status of national language [3]. The official languages of the Union Government of the Republic of India are Hindi in the Devanagari script[1] and English as an associate language. The Eighth Schedule of the Indian Constitution lists 22 languages at present, which have been referred to as scheduled languages and given recognition, status and official encouragement. Moving in depth to unravel the significance of a 'language' in context of India; there are certain points of note that come in the forefront as part of published literature on the specific non-Latin script—Devanagari, as follows:

- Sanskrit Alphabet and Indian Languages: As a liturgical language of Hinduism, Buddhism, and Jainism, Sanskrit has played an outsized role in India's linguistic development. From the perspective of Phonetics, all Indian languages have essentially the same alphabet derived from the Sanskrit alphabet. This common alphabet contains 33 consonants and 15 vowels in general practice. Additional 3–4 consonants and 2–3 vowels are used in specific languages or in the classical forms of others. This difference is not very significant in practice. Individual consonants and vowels form the basic letters of the alphabet [4].
- Devanagari as a base script for most languages in India: The Devanagari script is the widest used one, being used to write Hindi (the most spoken language), Marathi, Konkani, and Nepali, the language of the neighboring Nepal.
- Graphemes are at the heart of the printed Akshara: Different scripts use different philosophies for the individual grapheme's and their combinations. Some have a headline or *shirorekha* that persists for a whole word. Others have non-touching graphemes [4].
- Unique Typographical behaviors of Devanagari: Due to the unique typographical behaviors of Devanagari, typefaces have no predetermined character

[1]Devanagari is a complex script and contains a large character set due to the behaviors of the script, and as Bapurao S. Naik describes in his introduction to the *Typography of Devanagari*, '[The] peculiar nature of the Devanagari characters and their combinations create many difficulties in type setting.'

Fig. 30.1 Andrews K., Corporate alphabet, 2008. *Source* http://www.flickr.com/photos/91806538@ N00/2314668364/

set and contemporary typefaces usually contain around 1000 glyphs. Although the character set charts can be accessed through the Web site of Unicode and may be helpful for determining the needed glyphs, in the case of Devanagari the majority of glyphs within the font are not listed in the chart as they consist of contextual forms such as half-forms and marks.[2]

Certain points of note that come in the forefront as part of published literature on the Latin script for Roman English are as follows:

- Letters in the modern-day alphabet also imply the reading of symbols [5]. The letters in contemporary alphabets represent sounds, but their varied representations are vivid in the different design compositions of letters—this is reminiscent of logotypes of famous brands (Fig. 30.1).
- The research and development of Latin typeface suggest a better and more defined anatomy of Latin letterforms. Letters are made of linear and curvilinear strokes. Relative to Devanagari, the structural complexities are fewer in Latin. The strokes are uniformly simulated leading to unique structural arrangements in compositions using Latin (Roman English) letterforms. Based on the visual form of the Latin letter parts, they are easily relatable to the terms that define their identity (e.g., ascender, bowl, shoulder, ear, spur, bowl, swash, counter, and crossbar to name a few anatomical parts of the letters in Latin in Fig. 30.2).
- Letter formation and Technology association in Latin Script: The signs carved in stone are one of the first examples of typographic design. The way these symbols were built (flat brush and chisel) influenced the shape of each sign and of the alphabet. Function and technology work together to create characteristics, which make up the system [6].
- Latin alphabet—an impression of sound: Latin alphabets have been impressionistically interpreted as sound segments and are mostly considered units of phonemic writing [7]. Thus, supporting a conception of language (our focus for

[2]Ross, 'Non-Latin scripts: key issues in type design,' 134.

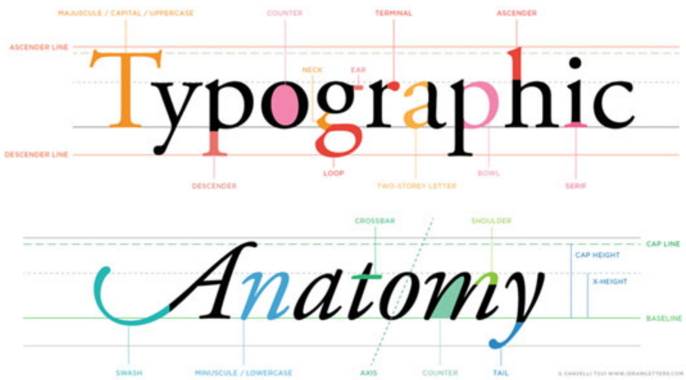

Fig. 30.2 Letterforms: Typographic Anatomy. *Source* Chavelli, calligraphy studio, 2015

the paper—English language); the Latin alphabet becomes both a model and an image in function (in the context of phoneme-grapheme correspondences).

In a nutshell, the application of certain tools and techniques to develop Devanagari (non-Latin) as well as Latin letterforms depends on the above-mentioned features associated as part of the letterform structure and syntax—that, in addition, guides the grammar of the language. The forthcoming sections, ‘Research Methodology’ and ‘Trifold Visual approach’ will showcase few such student designs in Latin and non-Latin letter compositions and a few letter expressions as part of expressive alphabet design assignments—floated as part of the courses on Typography at the Department of Design, Indian Institute of Technology Guwahati, Assam, India.

30.2 Research Methodology

The methodological approach that has been applied by each student designer takes into account the visual relationship established between the content and form of ‘the text.’ The text here differs with respect to the type assignment. The texts that prominently include arrangement of words are multimodal in nature (Figs. 30.3, 30.4, 30.5, 30.6 and 30.7). Whereas, the texts that include glyphs (characters) alone: letterforms and alphanumeric forms.

30.2.1 Understanding Multimodal Texts in Type Compositions

In reading images: The Grammar of Visual Design (2006), Gunther Kress and Theo van Leeuwen remind educators of the need to consciously help students develop the

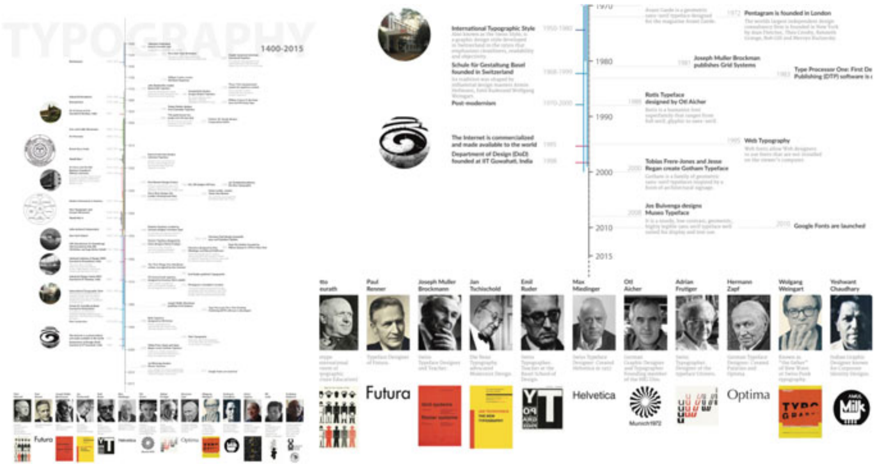

Fig. 30.3 Infographic Design to depict Evolution of Typefaces. Design by: Hriday Gami, M.Des, 2014–16, IIT Guwahati, *Source* Advanced Typography course, Department of Design, IIT Guwahati

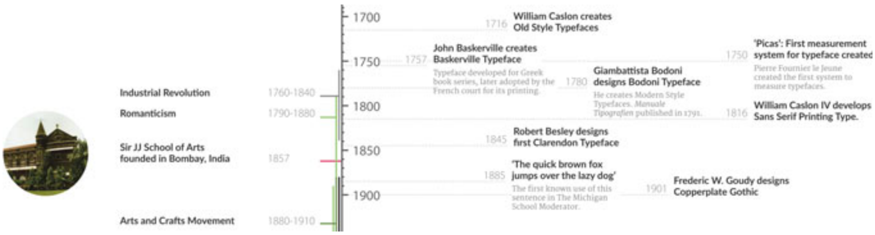

Fig. 30.4 Viewpoints and weight distributions in infographic evolution of typefaces. Design: Hriday Gami, M.Des, 2014–16, IIT Guwahati, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.5 View point showcasing eminent designers and their landmark typeface applications. Design: Hriday Gami, M.Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.6 Design of Type Quotations booklet. Design by: Nilutpal Buragohain, M.Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.7 Design of Type Quotations booklet. Design by: Honlung Ragui, M.Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

ability to make sense of all of the multimodal languages into a text. The text as the visuals of student works here in the paper discussed is viewed from the lens of semiotics. Students have applied multi-modes to represent text and churn out communication meanings as graphic designers and applied their learning of type, image, and the tools of expression as part of the course on typography. A multimodal text combines two or more communication modes, for instance, print, image (digital) or spoken text. In the context of semiotics in visual language, it combines two or more semiotics systems: linguistics, visual, audio, gestural, and spatial. The texts from Figs. 30.3, 30.4, 30.5, 30.6, 30.7, 30.8, 30.9, 30.10, 30.11, and 30.12 are digital representations of varied typographic assignments given to students as part of the course. The communication modes combined: image (digital) + later print submission by the respective student. For instance, the student design example in Fig. 30.3 showcases the multimodal text in three viewpoints explained in (a), (b), and (c) designed b the respective student designer. These viewpoints help design the infographic by combining 'Spatial' and 'Visual' modes of semiotics.

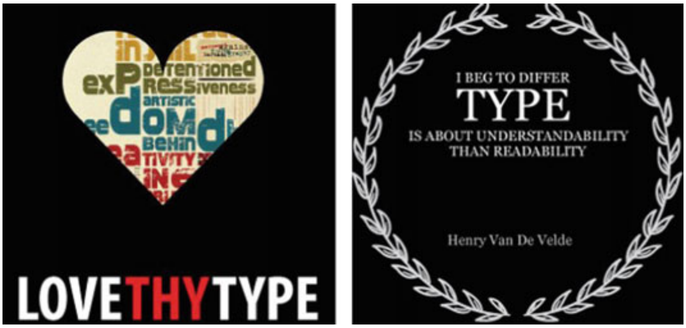

Fig. 30.8 Design of Type Quotations booklet. Design by: Senthil Kumar, M. Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.9 Design of Alphabet inspired by Gothic door arch. Design by: Shweta Gupta, M. Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.10 Design of Alphabet inspired by natural Banana leaf. Design by: Poonam Wagle, M. Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

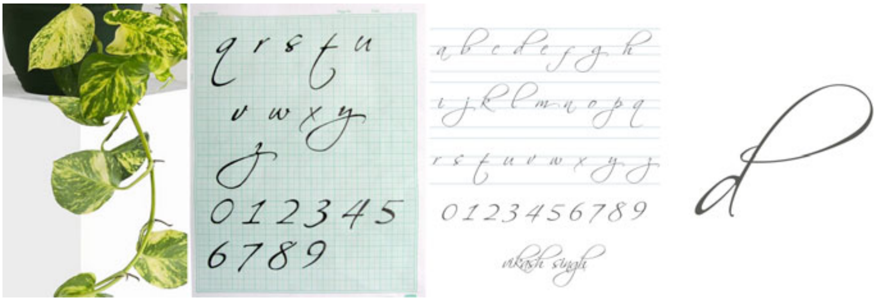

Fig. 30.11 Design of Alphabet inspired by the English Ivy Plant form. Design by: Vikash K. Singh, M. Des, 2014–16, *Source* Advanced Typography course, Department of Design, IIT Guwahati

Fig. 30.12 Design of future home number plate in Devanagari numerals ४७१ – 471. Design by: Hriday Gami, M. Des, 2014–16, *Source* Advanced Typography course, Dept of Design, IIT Guwahati

30.2.2 Syntactics and Its Applications in Type Compositions

Syntactics is that branch of semiotics that brings forth the formal properties of language and signs. In the visual student designs examples illustrated in present paper, syntactics has been used as another tool of creating an order and hierarchy in the text for visual emphasis. rather than any meaning generation that pertains to semantics (pure expressions).

For instance, in Fig. 30.5 student's design of a typographic booklet, the formal aspect of a uniform hierarchy has been used as a tool of expression to design the format of accordion folds to stage all 10 typographic quotations as a continuous symphony in the text. Individually too, each page composition too uses a simple typeface to depict the quotation with an interesting order achieved by exaggerating, breaking, displacing, orienting the group of letterforms (words) in a selective manner. Thus, the syntax (order) helps compliment the meaning of the quotation as a visual channel of the text.

30.3 Trifold Visual Approach

30.3.1 Language—The First Fold

Structure: The structure in language helps make the comprehension of letters, words, paragraphs, and texts better. Along with this, a structure in a language sets the context/the ground for the reader/consumer of the text. See Fig. 30.3 for a master's student's design in typography course with three modalities ('the texts' with respect to semiotics); they being: (a) the evolution of typefaces (right side column of the layout), (b) the direct and indirect influences of parallel design movements in the same time periods when respective typefaces emerged (left side column of the layout), and (c) parallel depictions of landmark designers—and how they incorporated the design movements and respective typographic evolutions in their landmark designs.

To decode these multimodal texts following tools of expression have been applied:

(1) **Context, Positioning and Weight distributions**: The student designer sets the context for the reader in 'diachronic evolution of typefaces,' with each evolution followed by date of its origin—set on the right side column of the layout design. This modality situates 'the text' in a visual position prominent enough on the page, along with descriptive text as part of the textual commentary explaining evolution of each typeface. The bold text (bold weight of the font) highlights the significant aspects of text to be retained by readers. For instance, 'William Caslon IV develops Sans Serif Printing Type' in 1816 that occurs at the backdrop of 'Romanticism' movement of the 1790s–1880s (Fig. 30.4).

(2) **Structure aids in making the 'space areas'** in the layout. This helps a graphic designer focus on certain prominent features in words and images. This can be specifically identified at the base of the design that narrates a story of how eminent designers have applied these typefaces in their landmark designs at different points of times in history of design (Fig. 30.5).

Syntax: Setting an order or sequence in words or groups of letterforms as part of varied compositions—helps provide a pattern that readers may identify with. Syntax gives a visual channel to the letterforms to convey an order of expressions (sometimes directly—denotations and sometimes in a subtle way—connotations).

See Figs. 30.6, 30.7 and 30.8; for three master's student's design in typography course; the designs explore a visual structure and syntax to communicate famous quotations by 10 pathbreaking Typographers of their times. The assignment was to design an entire ten quotations pocket booklet as a source of inspiration and idea generation for their future as young design professionals.

The syntax in the accordion flow of pages gives a macroview of the booklet as a unit composition—that acts as a channel to hold a bigger philosophy of typography in one channel/carrier of all 10 quotations together. As a contrast, the per page syntax design of single quotations have specific visual and expressive tools of hierarchy, emphasis and experiments in arrangements of group of words together—that act as an apparatus to fix the meaning of every quotation on one-page constraint. The flow here from one word to another guides the emphasis that the designer wishes to augment in the reader during the act of reading.

Cultural Basis: The subtle (or connotative) pattern is a deliberate choice of a designer or typographer to set the message as part of a familiar group of letterforms. This is the essential cultural basis that is associated with the language of the script. Figures 30.9 and 30.10 represent visual designs of different alphabets by students as part of their typography course at IIT Guwahati, wherein—the 'type forms' in designs of the alphabets have been a form inspiration from geometric forms/objects/artifacts/architecture, etc. or organic (nature-inspired) forms of construction around us with some cultural basis (social, religious, place-specific, historical, ornamental, locally popular, etc.) and show its application poster so that the theme of the alphabet design matches with the genre of the poster (movie/magazine/other forms of posters as per the alphabet).

30.3.2 Tools and Techniques of Production

Calligraphy: The spontaneous and expressive art of beautiful writing—calligraphy encompasses a world of tools and techniques. Historically, the need to communicate interpersonally was embedded in the symbolic forms—starting from the cave art paintings in Lascaux, France till the forms of modern 'picture writing' (or 'pictograms' to be specific). A few abstract lines came into modern-day representations of an object or thing and could be recognized by the audience—who too evolved parallel to the evolutions of tools—from bamboo and feather to brush and steel (metal make to now Biro/Modern pens such as the roller ball) [8]. Represented in Fig. 30.11 is an alphabet design using the calligraphic tool of brush and later digital metal pens to refine the final identity of the characters inspired from inorganic natural Ivy plant stems and leaves.

Manual Embossing and Engraving: To create a deeper impression and raised expressions of letterforms in paper, or other materials like wood, metal, clay, and plastics—both engraving and embossing (relief) enhances the craftsmanship of the artist/designer and gives viewers/audience a long-lasting form representing a heritage/culture of making design language manually. The thirdfold of the visual approach on Semantics (expressions) in student designs showcase embossed and engraved techniques, digitally reproduced (Figs. 30.10 and 30.11 ahead).

Digital Printing: It has been a remarkable journey in digital tools and techniques—a contrast to the old press technologies in function; but following the same typographic principles of typesetting in much better, faster, and easily mass-produced identities in-built in modern digital printing machines and equipment.

The digital-to-print connection, once paramount, is now only one task among many. This change affects all aspects of design, but perhaps none more than typography, where the readability of digital fonts depends so much on the environment of display [9].

30.3.3 Semantics (Expressions) and Meaning-Based Applications

Studies of linguistic signification through pre-established conventional signs formed the basis of important trends in the formation of semiotics [10] and as such familiarity with a sign on some level has always been a vital consideration of semiotics. In relation to this Van Leeuwen identifies the two fundamental principles that govern signification in typography, ‘connotations and experiential metaphors’ [11, 12]. Connotation is grounded socially in the prior use and practical history of the typeface, while experiential metaphor locates meaning in metaphorical connections to other objects and phenomena. Both of these sites refer to prior

Fig. 30.13 Design of future home number plate in Devanagari numerals ६७२ –672. Design by: Shweta Gupta, M. Des, 2014–16, *Source* Advanced Typography course, Dept of Design, IIT Guwahati

experience, but experiential metaphor, based on Lakoff and Johnson's conceptual metaphor theory, is a more complex and flexible process [12–14]. Sets of tri-digit Devanagari (non-Latin) and Latin (English language) numerals were allotted to students. There was an approach of both connotation as well as experimental metaphor used in the design concepts developed by students for the respective typography assignment. Represented are two visual designs of assignments (the connotative and experimented metaphoric designs respectively in Figs. 30.12 and 30.13) that required students to design the insignia (sign) plate visualized as part of their future homes in Devanagari Numerals.

30.4 Conclusions

Studies in the domains of type design and typography at large have encompassed around semiotics, tools and techniques, designing fonts for print/web and new dynamic interfaces and environments. Delving a little further, the purpose of this paper is to serve a new role in igniting interests of new age type design educators and practitioners toward making information on 'design research based approaches' available and better accessible to design community. For designing a complex set of letter designs and/or designs with typefaces as part of larger graphic design project (s), it seems pertinent to work toward a better informed and effective design by applying the new influx of approaches—such as, the three-fold visual approach of Language, Tools and Techniques of Production and Semantics (expressions) and meaning-based applications becomes a standard practice.

The three-fold framework in this paper is not only proposition of a structural approach of critical inquiry, but also serves as an analytical tool for design educators to develop teaching methodology when explaining the elements and principles of typography, hierarchy, grids, layout, visual emphasis and equity to students; more from their pragmatic identity within the paradigm of User Experience needs and requirements of the current digital age and the progressive future of the field ahead.

Acknowledgements This paper is dedicated to one and all of my Masters in Design students of 2014–16 batch—who undertook the course of 'Advanced Typography,' that I conducted as part of their syllabi at the Department of Design, IIT Guwahati in early 2015.

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Chapter 31
Influence of Lexical Semantics on Product Form

Manasi Kanetkar

Abstract Visual design often needs worded articulation and a written or spoken argument to be comprehended fully. Product attributes are described as words too. A design brief is essentially a worded statement, which then gets a visual form. Even while analyzing and or critiquing visual design, we use certain words or phrases. These words help a designer define the semantic attributes of the form. This paper aims at studying influence of the lexical role of a word (in a design brief) on product form. It questions the connection between lexical semantics and product form. This paper proposes a hypothesis that 'the noun or an action verb which dominates the product identity, whereas the adjectives will have their limited influence on the identity'. The study is a part of a larger project 'exchanges between the visual language and written languages'.

31.1 Introduction

This study aims to establish the effect of lexical semantics on product form and its elements. A product design brief is essentially a phrase or a sentence. Each sentence has a grammatical order, and the words have semantics roles to fulfill.

Lexical semantics is a subfield of linguistic semantics. Lexical units include not only words but also sub-words or sub-units such as affixes and even compound words and phrases. Lexical items contain information about category (lexical and syntactic), form, and meaning. The semantics related to these categories then relate to each lexical item in the lexicon.[1]

Ferdinand de Saussure proposed a theory which gave prominence to the internal structure based on cognitive thought process in structuring the physical (material) or intangible (abstract) signs of the environments or surroundings. Saussure's theory is

[1]https://glossary.sil.org/term/lexical-relation (visited on 2/5/2018).

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Smart Innovation, Systems and Technologies 135,
https://doi.org/10.1007/978-981-13-5977-4_31

considered to promote the thought that language does not reflect reality but rather constructs it since we do not only use language or give meaning to anything that exists in the world of reality, but also to anything that does not exist in it [1].

Lin et al. [2] proposed an approach using multidimensional scaling (MDS) for the building of a perceptual space, in which the perceptual attributes of a family of products can be described.

Smith et al. [3] had proposed a model to determine semantic category of a natural object, mainly birds and animals. It is assumed that the meaning of a lexical term can be represented by semantic features. Some of these features are essential for defining aspects of a word's meaning (defining features), while others are more accidental or characteristic aspects (characteristic features). They proposed typicality and atypicality and the grade of it of a certain member based on the similarities and the differences that it shares with the semantic category.

Athvankar [4] has argued about semantic profile of a product. Referring to the mental world of humans and the semantic space, he articulates that the human mind appears to map the concepts more holistically as a part of larger network. Thus, the identity of a product borrows from different semantic spaces, identity of the product and complexities of meaning depend on how it is linked to other concepts; most products can be presented a compound semantic statement.

A brief for product form can, therefore, be an **argumentative statement**, with each word contributing to the 'form semantics'.

Here is an example of a design brief (phrase)—'To design a portable, industrial grinder'. Based on Athvankar's theory (1990), we can assume that each word shifts the identity of the product some way or the other.

If we study these phrases from the viewpoint of grammar, each word fits in a category, e.g., a noun, verb, adjective, or an adverb. Lexical semantics (also known as lexicosemantics), is a subfield of linguistic semantics. The units of analysis in lexical semantics are lexical units[2] which include not only words but also sub-words or sub-units such as affixes even compound words, and phrases.

The sentences or phrases also have an inherent hierarchy. Most of the times, a design brief is either a noun phrase or a verb phrase. A noun phrase consists of a noun or a pronoun with a pre-modifier (adjective/preposition) and/or a post-modifier. A verb phrase consists of a verb and adverb.

This paper questions the connection of lexical semantics to product form. This paper proposes a hypothesis that it is the noun or an action verb dominates the product identity, whereas the adjectives will have their limited influence on the identity. In exceptional cases where it is new conception, it could the verb which defines the core function may evolve into an identity.

[2] https://en.wikipedia.org/wiki/Lexical_semantics (Visited 3/5/2018).

31.2 Method

Two separate experiments were conducted to establish the roles of noun, verb, and adjective. The participants were well versed with visualization and representation of product forms.

The participants were ten graduate students of design. Six groups, each comprising of four participants, were established. Each group had their own enclosed space and did not interact with other groups. They set up the stations and their performed 'warm-ups' for sketching before beginning the tasks. Each group had to perform two tasks as per the description is given to them.

The participants were asked to make quick representations or sketches depicting the word/attribute given. The tasks lasted for 20–30 min each were moderated on the spot to match the complexity of the word. Each group had common instructions 'to keep the forms simple yet communicative of the exact meaning'.

31.2.1 Experiment 1

Aim: To establish the dominance of 'noun' from the worded description on the product form.

Since the nouns had to be chosen, a list of day-to-day objects was identified. The objects needed to have a definite scale and volume and but had to be open for interpretation as well, in terms of form language. The other products could have been salt and paper shaker, paperweight, etc. Two products were chosen; one had a definite typicality—'*cup*'. The other product chosen was a '*container*' and students took the liberty to decide whether it was an open or a closed container (Tables 31.1 and 31.2).

Both the products chosen had inherently minimum features but also had enough to be a product and not an abstract form.

31.2.2 Experiment 2

Aim: To establish method of form generation from noun and/or the verb in the worded design brief as well as observing which of the two contributes more to the identity of the product.

An investigation with verbs led to an understanding that the verb had to indicate a clear action to result into a form or a visual. A list of such verbs that clearly indicated the action was compiled. The same verb was also converted to a noun (with the creative liberty of generating nonexistent words); so that the two could be put to a comparative study. The nouns were shortlisted so that it does not lead to a common understanding, does not have 'typicality' (Tables 31.3 and 31.4).

Table 31.1 Details of group-wise tasks for experiment 1 (product—*container*)

	Group A	Group B
TASK 1	Sketch a form to depict ONE of—organic, elegant, ornate, sporty	Sketch a form that depicts a 'container' as well as possible
TASK 2	Evolve selected sketches to become a 'container'	Evolve selected sketches to become either—elegant, ornate, sporty

Table 31.2 Details of group-wise tasks for experiment 1 (product—*cup*)

	Group C	Group D
TASK 3	Sketch a form to depict ONE of—corporate, fluid, natural, sporty	Sketch a form that depicts a 'cup' as well as possible
TASK 4	Evolve selected sketches to become a 'cup'	Evolve selected sketches to become ONE of—corporate, fluid, natural, sporty

Table 31.3 List of verbs and corresponding nouns

Verb as descriptive	Noun
Cuddles	Cuddler
Scares	Scarer
Swims	Swimmer
Stings[a]	Stinger[a]
Connects[a]	Connector[a]
Nods	Nodder

[a]Shortlisted pairs of nouns and verbs

Table 31.4 Details of group-wise tasks for experiment 2 (*verb/noun*)

	Group E	Group F
TASK 3	Sketch a form to depict the word '*stinger*'	Sketch a form that depicts the phrase '*it stings*'
TASK 4	Sketch a form to depict the phrase 'attaches/connects'	Sketch a form to depict the phrase 'attaches/connects'

The word 'attacher' was combined with connector, so as to not stick to the existing electronic/electrical connectors.

The explorations were documented in pictorial form and a feedback was taken from participants after the activity. Each exploration sheet was filled with appropriate nomenclature for documentation.

31.3 Results

31.3.1 Experiment 1

It was observed that the forms were indeed influenced by the noun the most. If we compare the forms generated from 'noun first' vs. 'adjective first', the one that started adjectives were pulled toward the typicality defined by nouns (refer to Fig. 31.1).

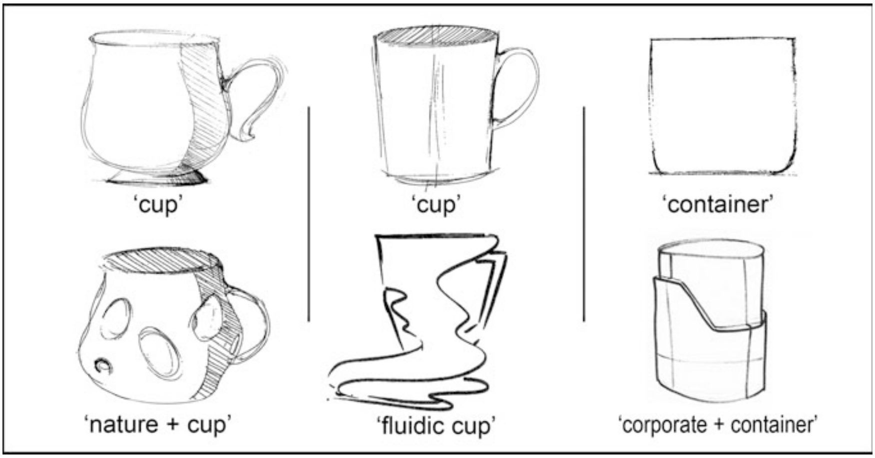

Fig. 31.1 Results of experiment 1: 'Noun first'

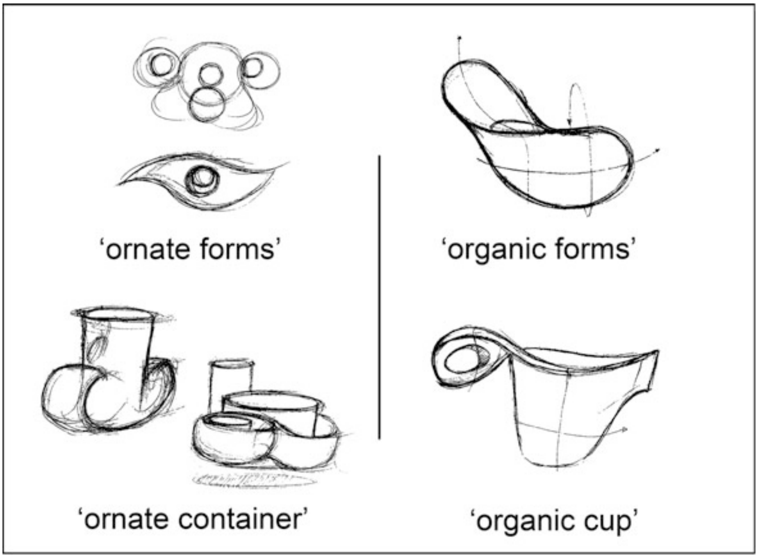

Fig. 31.2 Results of experiment 1: 'Adjective first'

There was a definite influence of the starting word on form. This was more effective with the word 'container' since it allowed itself to be translated in a flexible way (refer to Fig. 31.2).

31.3.2 Experiment 2

Comparison between forms that were generated from 'stinger'(n) and 'it stings'(v). The forms that came out of noun were more concrete, complete, and three dimensional in nature. The ones that began with 'it stings' focused on the function and were left open most of the times. They tend to be 'features' of a product. A similar observation was made with connector/attacher (n) versus it connects/ attaches (v) (Refer to Fig. 31.3).

It helped to have an action (verb) that was clear to visualize, i.e., sting. The noun/verb that was associated with existing products was more difficult to visualize. That is, the noun container was ambiguous and did not lead to a common understanding of a 'typical' container.

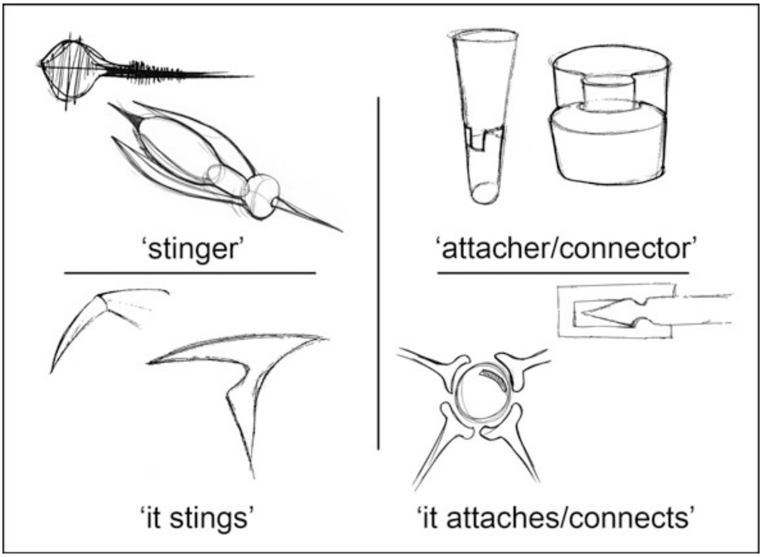

Fig. 31.3 Forms generated from 'action verb' and the noun generated from the verb

31.4 Discussion and Conclusion

It was observed that 'semantic role' of a word in the descriptive phrase used as design brief has an impact on the product form. It was also observed the noun describing a clear function/purpose defines the product form in a strong and direct way.

When the students started with an adjective or a verb, the explorations lead to a more free approach which resulted in open lines/open forms. Verbs lead to stand-alone features and open forms as well. On the other hand, the forms that came out from using a noun were closed and started getting more defined as a product complete by itself.

This implies that the typicality or identity of a product directly depends on the 'noun' used to describe the product.

31.5 Future Scope

Lexical semantics can be studied in detail to give a better insight into product form and probably visual language for graphic design as well. A deeper enquiry into structures of phrases and clauses can lead to unexplored areas of defining product attributes.

Attributive nature of adjectives and noun adjuncts and the similarities and difference between them can be explored. An adjective in the descriptive phrase can be either a pre-modifiers or a post-modifier and their effect on the form can be analyzed.

Classes in grammar like classifiers, determiners can be used to formulate a guide to construct a more beneficial descriptive for design.

A few design examples can be studied to understand how each lexical element can influence design elements like scale, silhouette, symmetry, bulk, and other finer elements.

This research would be an attempt to identify opportunities in all the aspects mentioned in the above excerpt and find unexplored ways of visual communication. There could be many possibilities unexplored in codification of the worlds' languages. Languages are always growing, evolving, and assimilating new words. The experts claim that the new media has helped the rate of creation and propagation of new words.

The investigation into exchanges between visual and written languages may lead to new ways of problem-solving techniques.

Gupta and Jain [5] proposed a computational tool for 'visual information retrieval' for Web-based visual information. Sheth [6, 7] has proposed multiple tools and models for information processing and establishing complex meanings, in the semantic Web space, for computational purposes, which have been successfully implemented for online shopping platforms. An extension of this study can be integrated with similar tools for them to be more effective.

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Chapter 32
Visual Perception of the Street Façade of a Historic Town: Case Study of the Walled City of Jaipur, India

Somya Mishra and Saptarshi Kolay

Abstract This paper aims to investigate the visual identity of street façades of historic Indian cities, according to the perception of users of the place. The major objectives of the study are to conduct user-centric evaluation of architecture of the street façade of the heritage precinct, to prioritize the architectural elements of the street façade and validate it through semiotic analysis and to establish a visual identity of the historic Indian city for the users according to their visual perception. To achieve these objectives, the study uses semiotic tools to analyze the architectural elements of the buildings in the study area. The characteristics of the architecture of the heritage area in most used market space of Jaipur are studied. The architectural characteristics of the elements, like columns, cornices, arched windows, eaves, ornamental parapets, and motifs, give identity to the image of Jaipur. These findings may support the policy framework that enhances the visual image of the city.

32.1 Introduction

An environment that focuses on human experience and is designed according to user preferences has the ability to enhance urban quality. Recognizing these requirement and finding ways to address those falls in hands of the designers, where a gap is experienced [4, 14]. According to Kevin Lynch, a city is called legible if it has its identity in mind's eye, is easily recognizable, and has its own unique structure of identification [10]. Although this identity can be very different for different people according to their perceptions of the place, if designed properly, a common visual image can be established for everyone [2, 8, 14].

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Jaipur is one such city, where architecture forms its identity and that identity has been intact from the eighteenth century. In modern times, the unplanned development in historic cities has destroyed the viewscape of the otherwise beautifully designed aesthetics. As Lynch has pointed out, life is not impossible in such places, but the quality of life can be better if the urban quality is maintained [1, 2, 10]. Moreover, viewscape of a heritage precinct has an important role to play in order to have an understanding of this historic environment in towns and cities [1, 3–6, 9]. There are several studies on perceived quality of urban environment that try to establish a harmonious relationship between architecture of this viewscape that include streetscape and landmarks, and people around it [1, 2, 4, 5, 8, 11, 12, 14].

In the Indian context, studies and research focusing on the visibility of historic streetscapes and the preservation of their view are not given importance. But there is a need for such research to protect the views and to sustain the cultural as well as the architectural identity of a city. These landmarks are constantly threatened by surrounding urban development which obscures the traditionally enjoyed views. This study attempts to fill that gap by studying the architectural elements that become its identity in the present scenario.

32.2 Literature Review

The literature was studied to develop an understanding of the application of semiotics in architecture through which data collection and analysis framework were prepared.

32.2.1 Introduction to Semiotics

Umberto Eco believed that semiology is not only a theoretical study, but also includes methodological ways of semiotics. Thus, he came up with a broad definition for semiotics. 'Semiotics is concerned with everything that can be taken as a sign' [3].

In contrast to Saussure's model of the sign in the form of a 'self-contained diad', Peirce offered the triadic model:

- The representamen: the form which the sign takes (not necessarily material);
- An interpretant: not an interpreter but rather the sense made of the sign;
- An object: to which the sign refers.

Architectural qualities can be broken down into four parts—spatial organization, physical structure, social parameters, and cultural parameters. The first two parameters can be combined to call it the mechanics of architecture, mainly dealing with the functioning of the built environment. The last two parameters can collectively be called sociocultural background of the built environment [4–6, 8].

32.2.2 Semiotic Tools of Assessment for Architecture

According to Louis Herbert, in his book ‘Tools for Text and Image Analysis: An Introduction to Applied Semiotics’, has given 10 tools for semiotic analysis of texts and images [9]. The study considers façade as one composition and thus transforms it into an image. This way, the architecture of street façade, qualifies for the semiotic analysis.

32.2.3 Ornamentation and Decoration

The ornamentation can be seen at edges of districts, at entrances of streets, at corners, at crossings, traffic pause points, major viewscape, etc. The amount of ornamentation is also determined by the maintenance needed for the ornaments and where they are placed [11, 12]. Ornament and decoration have three interrelated functions [11, 12]. They are to give a locality a theme by having same elevation treatment, to enhance the physical and social qualities of an area, and lastly to develop the image of the city.

32.3 Research Methodology

The study started with the review of established knowledge regarding this field in the literature. This led to the research gap identification and approach to fill this gap. The approach chosen has to be justified by doing case study of already tried and tested methods. In this case, studies were selected by its use in the study, i.e. for methods of data collection and for using the data to arrive at desired result [15]. The data collection processes emerged after this step and the data was synthesized using semiotic tools. The principal results from here were used for the visual preference list generation leading to the visual identity designs of the city.

32.4 Site Study

32.4.1 Study Area Introduction

The primary architectural style followed in whole city was Maru–Gurjara style, which directly translates to the architecture of desert. Maru stands for desert and Gurjara to the community that originally inhabited the place, as explained by one of the respondents in survey. Surveys also revealed about lesser known fact that the city was developed in phases and each phase made certain changes in the existing

Fig. 32.1 Elements chosen by people in survey. *Source* Author

structures [7]. The present form that we see now is a result of many years of evolution and exposure to various ideologies. Johari Bazar was chosen as the study area due to variety of activities and the presence of landmarks [13]. This variety of built use and various backgrounds of users bring in different perceptions to study. The stretch that was studied started from Sanganeri Gate and ended at Badi Chaupar. The main landmarks of this road are the Jama/Jama Masjid, the Sanganeri Gate, and Badi Chaupad/Chaupar.

The data collection strategy involved the use of sample of 30 individuals, all either visitors, shoppers, shopkeepers or residents of the Johari Bazar area. A set of 32 questions were asked for the study where people had to identify the characteristics and architectural elements of the city, rank the elements from mood board on the Likert scale and finally tell about the context and history of the place [14] (Fig. 32.1).

32.5 Analysis

The semiotic tools used for analysis have been discussed earlier in the literature review. The three methods derive information from each other at different stages [9].

32.5.1 Tool 1—Structural Relation

The first step for this analysis is a selection of the facade that has to be studied.

Step 1—Elements' Selection. The elements that are under observation have been taken from survey results. The elements that are most recognized by people will be studied on the street facades.

Step 2—Typology of Relation. The typology of relation between these elements can be studied under the main head, semiotics and architecture. From the literature, these subheads which have been used are physical structure, social parameters, and cultural parameters (Fig. 32.2).

Step 3—Expression of Relation. After identifying the possible relations between the elements from the street façade, the relations are applied to elevations of street. The four relations that have been observed here are:

- Colour—The colour palette chosen by people has 'Jaipur pink' which is common to the whole walled city.
- The next relation seen in the street elevations is repetition of a shape, called as 'Jaipur's symbolic shape' by respondents. The shape can be seen everywhere, as borders on cornices, top edge of the gateways and even on the bounding wall of the walled city (Fig. 32.3).
- The wall paintings: These paintings are done on surkhi plaster finish walls with white lime paste. The designs are mostly geometric, replicating door and window frame designs with flower vases painted inside at some places. These

Fig. 32.2 Colour palette chosen for Jaipur. *Source* Author

Fig. 32.3 **a** Signage with ‘shape of Jaipur’ and **b** ‘shape of Jaipur’ helped in recognition of door. *Source* Author

Fig. 32.4 Wall painting from walled city. *Source* Author

patterns have come from the block prints’ design of Sanganer area, and the art is known as Sanganeri block print (Fig. 32.4).

Step 4—Establishing the Relation. Thus from the previous step, it can be inferred that buildings on the street façade have a very strong relationship with each other, which is not just about the use of architectural elements. The established relations are

- colour,
- shapes, and
- painting patterns (Table 32.1).

32.5.2 Tool 2—Operations of Transformation

Step 1—Element Selection. A façade for the study was selected.
Step 2—Characterization. The first character of façade is that it has traditional element in the background.

Table 32.1 Steps 2 and 3 of operation of transformation of semiotic analysis

Step 2—Disintegration	Step 3—Classification
	The background
	The middle ground
	The foreground

The second character is seen in particular window design and jharokha design. The arches are also a common character. Characterization can also be done based on elements that appear in foreground. These can be signage, hoardings, frontage, cornice, eaves, etc.

32.5.3 Tool 3—the Semiotic Square

The third tool has six steps, starting from element selection, breaking it into meta-elements, establishing the relations between these meta-elements, making design iterations by photomontage techniques under step of operations, again making observations, and finally the classification. The observation stage in this step has also been used for validation by using eye tracker. The relations and characterizations are taken from previous steps and used here for further analysis. The details for each step have been explained below.

Step 1—Element selection. The same street façade is selected for analysis.

Step 2—Meta-elements identification. The meta-elements are the elements we got from the disintegration of façade in steps 2 and 3 of the previous tool.

Step 3—Expression of relations. The relations expressed here are taken from step 3 of tool 1. The all possible relations amongst elements on façade are colours, shapes, and wall paintings.

The relations expressed here are taken from step 3 of tool 1. The all possible relations amongst elements on façade are colours, shapes, and wall paintings which have been considered here (Figs. 32.5 and 32.6).

Step 4—Operation. The iterations are done by photomontage to change colours and elements on façade. Some iterations are changing doors, windows, cornice designs, colours, wall paintings, etc.

Step 5—Observation. This step has also been used for validation of results from the previous steps where people were asked to identify which images from the previous step are of Jaipur. Their eye movements were tracked to see that the elements that they say that they identified are same or not. The heat maps were generated to get results.

The eye tracking results show that the points that capture people's attention, and in this case, even help in recognition depend upon the scale of the view. For example, in Fig. 32.7, it is seen that elements like chhatri, jharokha, and window captured their attention.

Step 6—Classification. For classification, the relations established from previous tools were used and tested and then validated. On testing the street façade, architectural elements can be considered very important as inferred from the eye

Fig. 32.5 Façade after changing colours. *Source* Author

Fig. 32.6 Iterations in signage design. *Source* Author

Fig. 32.7 Heat map of identification by signage. *Source* Author

tracking results. But when the results for other images are considered, it is clear that colour, design elements, wall paintings, etc., are more important. Thus, the elements can be classified as ornamentation, colour, traditional elements, and signage design.

32.6 Findings

32.6.1 Visual Priority List

The visual priority list of elements that according to people, creates architectural identity of the place, has been prepared. The elements were identified through user preference survey and priority was decided after semiotic analysis. The list starts with colours, eaves, motifs, signage design, gateways, surface materials, arches, jharokha, roofscape, and ends in chhatri and jaali design.

32.6.2 Visual Palette

The elements that were identified by people were broken down further to get the key meta-elements that gave them the identity. The meta-elements chosen have been disintegrated and layer of colour and texture has been added to it. First is the design on cornice and eaves (Figs. 32.8, 32.9, 32.10, 32.11, and 32.12):

The last element that according to this analysis, creates identity of Jaipur, is the gateways (Fig. 32.13).

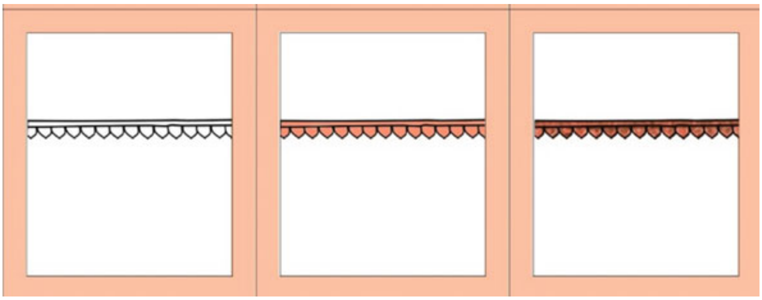

Fig. 32.8 Cornice design of Jaipur. *Source* Author

Fig. 32.9 Signage design of Jaipur. *Source* Author

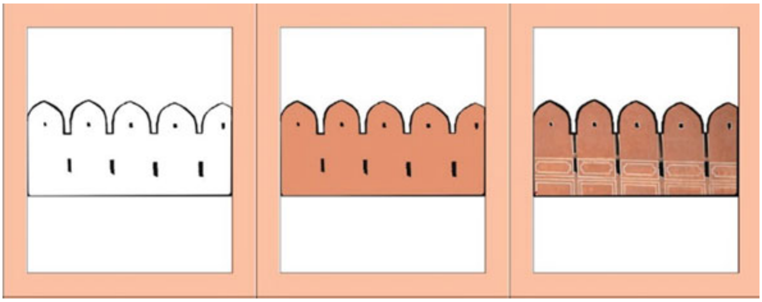

Fig. 32.10 Roofscape design of Jaipur. *Source* Author

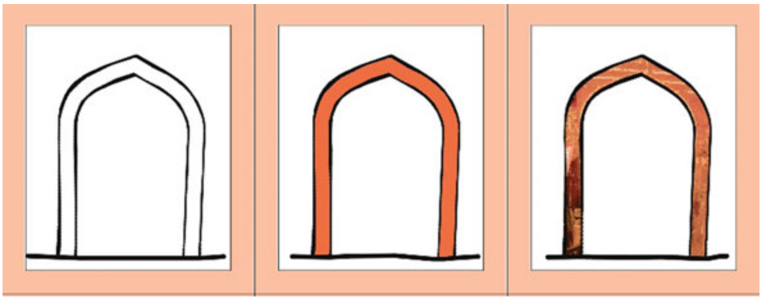

Fig. 32.11 Pointed arch used in gateways of the Walled City of Jaipur. *Source* Author

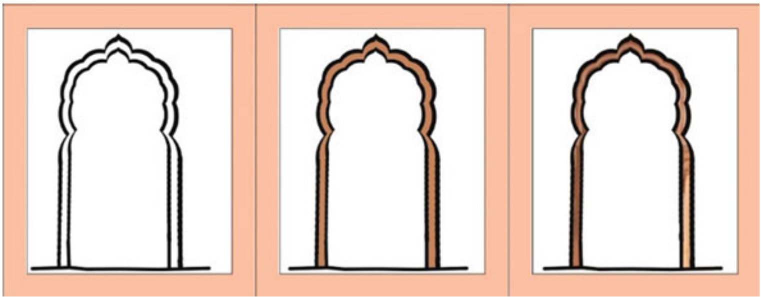

Fig. 32.12 Moorish arch used in Jaipur. *Source* Author

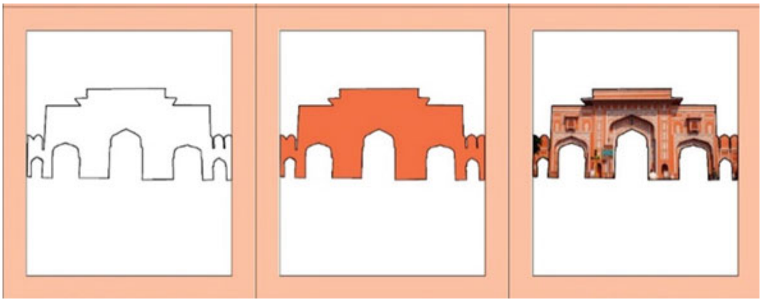

Fig. 32.13 Massing of gateways in Jaipur. *Source* Author

32.7 Conclusion

The aim of this study was to investigate the visual identity of Indian cities with historic relevance in terms of architecture. The outcomes were a visual palette and priority list of elements of architecture that, according to users of the place, define the identity of heritage area of Jaipur. The user preference survey also reveals the importance of architecture for people and how they relate to it.

32.7.1 A Common Visual Identity

The user preference survey shows that Jaipur has a strong visual identity in minds of local residents. This shared identity is reflected in the survey results where people chose a particular type of arches, roofscape, traditional elements, etc. The survey also revealed that the history of the place has a major role in the creation of this identity and people of the place have knowledge about this historical background.

They relate these stories with architecture and create their own perception about architectural identity of the place.

32.7.2 Validated Priority List of Elements

The list of elements, arranged according to priority in identification, after analysis using semiotic tools shows the importance of articulation and ornamentation of street facades. It is through the elements like wall paintings, cornice design, door–window frames, etc., that people recognize Jaipur. Thus, it can be said that ornamentation plays a vital role in street façade design.

32.7.3 Visual Palette

The visual palette created as the last step of this study shows the elements that form identifying features of architecture of the area. The elements have been broken down to meta-elements and their importance is established through validation. The elements like cornice details, wall paintings, and massing. grabbed viewer's attention first and helped in recognition of the place. Thus, they have been used in the final palette that can be used by urban designers and planners while proposing street facades of new developments in the city.

32.7.4 Way Forward

The study gives a palette of elements for designers to use while planning street facades in new developments. The same methodology can be used to investigate user preferences in these heritage areas and show their significance. The methodology can be used by other researchers to create similar element palettes for other heritage areas in India.

The analysis tools used here can also be applied to individual building facades and identity of certain buildings, that have an iconic image attached to them, can also be examined. Moreover, the study can be expanded to the analysis of spatial planning in heritage areas of Indian cities using the same methodology.

The list of elements that came as a result of the survey can be used by designers and planners to come up with urbanscape that is more sensitive to the context. These elements are key identity makers of the architecture of the area and the people of these heritage precincts relate with them the most, visually.

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Chapter 33
A Review of Eye Tracking Studies Related to Visual Aesthetic Experience: A Bottom-Up Approach

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Abstract In the context of visual aesthetics, a bottom-up approach deals with the features of the visual stimuli such as form, texture, color, novelty, complexity, composition, contrast, and order. These features influence subject's perception during an aesthetic experience. As per philosophy, both subject and object should be present to have an aesthetic experience. Though there are several attempts reported by the researchers to evaluate visual aesthetics using biometric technologies, eye tracking has been found to be an efficient technique to investigate bottom-up aesthetic processes that operate with both object and subject. As reported by earlier researchers, the eye tracking-based studies convey meaningful visual aesthetic properties from visual exploration patterns of the subjects and have been reviewed thoroughly in the present paper. Different types of human visual behavior during aesthetic visual exploration (specific and diversive) have also been mentioned with citation of earlier works. Most of the reported eye tracking-based researches are limited to saliency study and have used unstructured variables to evaluate visual aesthetics. It has been observed from the available literature that the level of complexity and quality of composition of the visuals may be considered as the well-accepted measures to judge the aesthetic experience. Association of various sub-variables of composition (symmetry, balance, and proportion) and complexity (number of elements, variety of elements, and order of elements) with different eye tracking variables (fixation frequency, fixation duration, and first fixation) has already been reported by the researchers in a discrete manner. Hence, there is a need for the future research to establish correlations between various eye tracking variables and the measures of aesthetics with the ultimate aim of objective-measurement of visual aesthetics.

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33.1 Introduction

The term “aesthetic” functions as an adjective, therefore, several words like aesthetic emotion, aesthetic judgment, aesthetic object, and aesthetic experience are found in the literature. Broadly, aesthetics is studied in the fields of psychology, philosophy, and neurology. The concept of aesthetic experience may appear unclear due to different theoretical frameworks present in diverse fields and it is also very difficult to attend the specifics of it. Aesthetic experience is a state of mind influenced by aesthetic objects/visuals. According to philosophy, an aesthetic object may be a natural one or an artwork but aesthetics couldn’t explain why one is a work of art and the other not? [1]. This means every object comes under the jurisdiction of aesthetic experience. As per both philosophy and psychology, during an aesthetic experience subject and object, both should be present [2]. In the time of an aesthetic experience, object is engaged with the subject’s mind and leaves an impression in mind. This impression is hedonic in nature that may be positive or negative in notion and shadows surrounding environment [3]. During this phase, the attention level of the subject is observed to be very high by centering attention on a limited stimulus field while losing self-consciousness with no sense of time. It is also called as ‘narrowing of consciousness’ [4]. A similar state of mental focusing of attention can be observed in many psychological theories related to aesthetic experience like Maslow’s peak experiences [5], the concept of absorption [6], and Czikszentmihalyi’s notion of flow [4].

Philosophers and scientists always have the conflict of opinion between the subjective and objective approaches. Both subjective and objective approach has their advantages and disadvantages. Aesthetic research is a mix of both kinds of approaches followed by empirical proofs. There are certain psychological models that determine the information flow from object to the subject during an aesthetic experience with cognitive processing of the information. Such a model with five stages and two outputs was proposed by Leder et al. [7]. Apter [8] proposed that aesthetic experience is a self-rewarding cognitive process and not a goal-directed feature. This means when subject observe the aesthetic properties of an object, a different set of neural operation starts in the brain. The same was supported by the Leder et al. [7] with the information processing model but the phenomenon was proved scientifically by Cupchik et al. [9] through neural correlations. Functional MRI-based experiment showed that the areas of the brain like left and right insula, left superior parietal lobule along with left lateral prefrontal cortex were highly active during the aesthetic experience. From earlier research, it was confirmed that these respective brain areas were responsible for emotional and self-referential brain process.

Aesthetic experience is a combination of both top-down and bottom-up process as per information processing. Top-down information processes are controlled by the person’s perception, which is environmentally influenced. Thus it is very difficult to control. In contrary to this, bottom-up information process deals with the structural composition of the aesthetic object [10]. Cupchik et al. [9] proved with a neural correlation that aesthetic experience is a function of the interaction between the top-down orientation of attention and bottom-up perceptual input. Most of the psychological models associated with aesthetic experience are based on the top-down approach but Leder et al. [7] proposed an information processing model that holds both of the approaches. Prerequisite of their proposed model is that subject must view an object as a work of art. For the aesthetic experience of a natural object, this model doesn't hold firm.

The bottom-up process of aesthetic information processing depends on the composition and complex features of the aesthetic object [11]. At the same time, the bottom-up aesthetic experience is independent of the emotional, environmental, attentional, and cognitive factors. Many researchers suggest that bottom-up information processing during an aesthetic experience is affected by symmetry [12], balance [13, 14], contrast, [9, 15] etc. For example, during an aesthetic viewing, one subject is asked to focus on a region of interest (guided viewing/content awareness task/information search task) with some information and another subject is asked to free view the same visual. The first subject with guided viewing would acquire information in top-down manner and the second subject with free viewing would acquire information in bottom-up manner during the aesthetic experience. The reason might be that in bottom-up information flow, lower-level variables (color, form, texture, etc.) are first identified than these lower-level variables are linked together to form a holistic view, where no motor control activity is involved.

In a bottom-up process, the change in perception is always sensory driven as human perceives information through their sense organs. Vision as a human sense plays a huge role in perceiving the external environment. Human perception is dominated by the vision in comparison with other senses like auditory and tactile. In other words, visual information dominates all other forms of sensory input when visual aesthetic experience in concern [16]. Therefore, eye tracking is a fast and reliable technique among all available biometric techniques. It helps to receive biometric signals from human eyes to interpret the visual behavior of the subject during an aesthetic experience. From the literature review, it is observed that eye tracker is an effective tool to monitor visual attention [17, 18] during bottom-up aesthetic information processing. A limited number of publications dealing with eye tracking in human behavioral research have been identified. When it comes to the field of aesthetic evaluation, the number of publication drops further. Perhaps the interpretation of continuous stream of eye tracking data to understand human visual behavioral characteristics is a tedious task.

There is a constant argument between formalist and sentimentalist over aesthetics evaluation. When formalist justifies the objective approach to the aesthetic evaluation, sentimentalist doesn't support that. Moreover, there is no consensus regarding the advantage of one technique over another (subjective vs. objective evaluation) when it comes to the evaluation of the aesthetic experience. Bottom-up information processing is influenced by individual graphical elements (position, color, size, shape, orientation, etc.) which interact among themselves to create compositional and complex features of the aesthetic object. The visual composition and complexity directly affect the aesthetic perception. The eye movement behavior has been studied by various researchers [17, 18, 29, 34, 40, 43, 47] in the context of aesthetic decision-making, varied attention level, the role of art training, repetition of visual information, visual interest, and different cultural factors along with the cognitive functioning of bottom-up processes.

Aesthetic experience is a multidisciplinary as well as subjective domain with a wide range of application (dance, poetry, product, literature, artworks, human itself, etc.). The aim of current review is to identify the cognitive functioning of aesthetic experience and establish the relation of the aesthetic variables (complexity and composition) with the eye tracking variables, by citing the earlier research publications. Since eye tracking technique is an effective methodology to monitor the visual attention during lower-level information flow, the scope of this article is to limit itself to the bottom-up approach. Authors have segregated and represented different eye tracking studies with their behavioral interpretations during the bottom-up information processing of the aesthetic object. An attempt has also been made to identify the visual aesthetic measures which could be quantifiable through eye tracking variables.

33.2 Cognitive Functioning of Bottom-up Process During Aesthetic Experience

An aesthetic object can be perceived differently by different individuals. This happens due to various influencing factors like attention, aesthetic attitude, type of aesthetic object, art training, culture, and environment. Gombrich [19] used to believe that “art is incomplete without the perceptual and emotional involvement of the viewer.” Thus, an aesthetic experience can be explained as the result of both perceptual and emotional consequences. In this context, both philosophy and psychology converge on the functioning of aesthetics. Adelson [20] mentioned about von Helmholtz who first scientifically supported the fact of two-way information flow (top down and bottom up). Recently, some of the fMRI studies [21] suggested the activation of a different set of neurons during the top-down and bottom-up information flow. There are several psychological models along with some neuroimaging correlation of aesthetic information flow but still, there is no model that can completely represent the cognitive process during the visual aesthetic experience. Hence, in the coming section, literature pertaining to establishing the relationship between the neural activity and cognitive process during an aesthetic experience has been discussed to get the insight.

In existing philosophical, psychological [7] and neurological [22] framework; some aspects are common by involving a higher level of attention with an emotional output. Though psychological models are good for philosophical thesis, it’s very difficult to establish the hypothesis with experimental evidences. It is a continuous hit and trial process based on logic to establish neural correlations during an aesthetic experience. According to the different framework on aesthetic processing, cognitive process is a multi-stage, multi-loop, dual output, feed forward system with parallel as well as series processing of information. The framework proposed by Chatterjee [22] was based upon the visual neuroscience. Chatterjee's framework has been found to be very relevant as the current review is focused on the use of eye tracking to evaluate aesthetic experience.

The proposed model by Chatterjee [22] was based upon the three levels with two outputs. The first level is directly linked to the extraction of simple visual components like shape, color, texture, and proportion. The second level groups and segregates basic components to analyze visual composition and complexity. The third level derives semantic meaning from the intermediate vision that is directly linked to the memory. As a result, emotion and aesthetic experience are evoked. While doing the neural correlation of the above-justified process, it is suggested that first level or early visual process happen in the occipital region of the brain. Similarly, second level or intermediate level involves extrastriate cortex with frontal-parietal attentional circuits. As third level or late vision is directly linked to the memory, it has the access to any part of the brain. Medial and orbital cortices, anterior medial temporal lobe become active during an emotional output Chatterjee [22] also justified the universal nature of early and intermediate levels while restricting late vision from universal nature due to its link with subject's memory. The emotional output of the framework with neural correlation is not justifiable as it is not possible to differentiate two emotional processes in the brain [23]. Therefore, it can be assumed that aesthetic emotion is an independent emotion.

33.3 Eye Tracking of Visual Exploration Pattern and Human Behavioral Interpretation

Combination of top-down and bottom-up process can contribute to the better understanding the cognitive aspect of aesthetic experience with the multiple stages of operations. Visual exploratory pattern and its corresponding human behavioral interpretation can elaborate the cognitive functioning during an aesthetic experience. There are several image perception models based on the human visual scanning behavior, in the field of visual aesthetics. From the literature, it is observed that visual composition and complexity affect the viewing pattern. Mackworth and Morandi [24] first represented a framework for visual attention based on information theory. Later, the same method was used by the Antes [25] to record eye movements to study visual perception. Later on, this method provided a basic platform to guide other researchers in visual exploration study using eye tracking. There are two basic parameters for the visual exploration: duration of the fixation and length of the saccade. The eye movements with long saccade and short fixations were observed in high-density information contents. Earlier, Berlyne [12] classified two types (specific and diverse) of visual explorations with different motives. He found that while viewing a picture, initial eye saccades were long and the fixations were short. After a few seconds, longer fixation and smaller saccades were observed. The main purpose of random exploration might be the search for the information contained in the stimuli. This type of visual exploration is called as "specific" visual exploration. Similarly, after some time the gaze becomes shorter with the local overview of the stimuli, that type of exploration is called "diversive" visual exploration. Few researchers have verified how fixation gets longer in duration and shorter in length by plotting fixation against time [25]. Molnar [26] recorded first 1000 eye movements during 5 min of painting viewing and studied fixation duration and saccadic length. While verification of the obtained result with earlier findings, he also found the transition point of the visual exploration from specific to diversive happens between fixation number 5–9.

Yarbus [27] reported some of the universal eye movement strategies. He reported that the fixation is high in the semantic-rich area of the stimuli and not in the high-density area but he could not justify whether higher fixation is due to semantic-rich information or due to compositional variables of the image. Kaufman and Richards [28] observed that due to the physiological constitution the center of gravity of the image is explored more. Yarbus [27] also noticed that eye focuses on the center of the stimuli. He also reported that after the full exploration (specific and diversive) of stimuli, eye concentrates on the same local points. Molnar [26] experimented on two groups classified with semantic and aesthetic viewing. He found that aesthetic group explored the stimuli slower than the semantic group. Perhaps the reason might be aesthetic exploration is a higher cognitive task.

Similarly, Mould et al. [29] did an eye tracking experiment to evaluate human emotional response against aesthetically pleasing images produced by non-photorealistic renderings (NPR) algorithms. In another experiment, researchers [30] tried to classify the affective intention through eye tracking data. They have verified the result with a support vector mechanism algorithm to classify the affective intention. Among two experimental groups, the affective task group showed higher fixations and showed bigger average pupil size than the cognitive task group.

There are several types of approaches to the eye tracking study. Different types of eye tracking protocols include free viewing, guided viewing, content awareness task, information search task, and object recognition. Task-specific viewing is a top-down approach, whereas free viewing is considered as a bottom-up cognitive approach. During task-specific viewing, cognitive load affects the pattern of eye movements [31]. Wallraven et al. [17] conducted an eye tracking experiment to rate visual complexity or aesthetic appeal of the paintings. Global search patterns were observed with lower local fixations in aesthetic appeal. Moreover, wider fixations were observed in an aesthetic appeal compared to visual complexity viewing.

33.4 Measure of Visual Aesthetics and Its Association with Eye Tracking Variables

The bottom-up approach is capable of measuring attention during the aesthetic experience [17]. There is also evidence that increase in visual complexity in the stimuli, change the compositional value of the stimuli during the aesthetic experience and vice versa. Complexity and composition are the variables that affect aesthetic experience with the emotional output.

Recently, a few researches [32] have justified the use of these aesthetic variables (complexity and composition) through eye tracking. The available type of evaluation techniques have been shown in Fig. 33.1 along with the relationship between eye tracking variable and aesthetic measures during bottom-up information flow. In the coming section, this relation will be explained with some existing research work. From several psychological and neurological models, it is observed that attention of the subject is a crucial factor to have an aesthetic experience. Visual attention gets affected by the visual complexity and composition of the stimuli. Visual scanning behavior also changes with the variation in attention level.

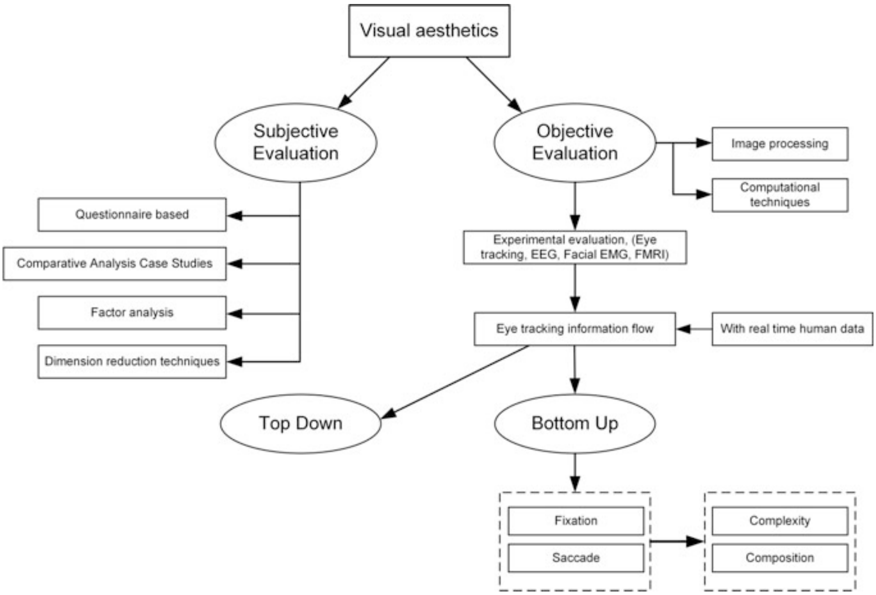

Fig. 33.1 Schematic diagram from review findings, showing the relationship between eye tracking variable and aesthetic variable during bottom-up information flow

33.4.1 Complexity of Visuals and Its Association with Eye Tracking Variables

Complexity is defined by the balance between order and chaos. The term complexity was coined in psychology by Hochberg and McAlister [33]. The introduction of complexity started with the objective evaluation of the aesthetics. There were earlier attempts to evaluate aesthetics through objective evaluation of complexity but the researchers were criticized due to non-consideration of the semantic aspect of the aesthetic experience. There are several empirical evidences that show perceptual complexity exhibits an inverted U shape (wound curve) relation with visual complexity [12]. Visual complexity affects attention of the subject and it also helps to identify the compositional patterns in an aesthetic object. Patterns help to understand and process the semantic meaning of the visual stimuli [34].

Berlyne [35] in his book discussed the variables of the perceived complexity. He mentioned that “Rated complexity has been found to increase with the number of independently chosen elements in a pattern, the number of attributes distinguishing elements, and the number of forms that each attribute can take.” Martindale et al. [36] worked on Berlyne’s theory and made a series of experiments to measure visual complexity. The complexity of the stimuli was measured by the number of curves present in the random polygons in a complex abstract painting. They discovered that semantic information is a good predictor of aesthetic experience compared to the complexity and they also found that art training doesn’t affect the result. Roberts [37] did an experiment on visual complexity by taking seven variables of the complexity and found that aesthetic preference was mainly governed by the three aspects of complexity. These aspects are amount and variety of elements; recognition and scene organization; and asymmetry.

The problem with the subjective evaluation of aesthetics is the inconsistency of subjective ratings. Objective measurement of complexity was started with the simple visuals like primitive shapes [38]. Earlier it was not possible to measure complex paintings with deep semantic meaning. Therefore, a computational method called “chessboard method” was developed to evaluate the complexity of the paintings. In this method, a visual object has to be divided into the large numbers of squares and those squares are analyzed with the different level of grays as per their color tone [26]. This discretization of visual elements is quite common in image processing field. Several computational aesthetic studies were reported in the luminous and color study using the similar method [39]. The demerit of this computational process is that it doesn’t consider subject’s perception which is crucial for an aesthetic experience. Therefore, eye tracking technique is found to be suitable for evaluation of visual aesthetic experience where both collative properties and semantic information are present.

From the literature, it is observed that perceptual complexity cannot be measured directly from eye tracking variables. As perceptual complexity affect attention and attention can be quantified from eye tracking variables. From the pattern of eye fixation, it is observed that complexity is directly proportional to the visual exploration. Mühlenbeck et al. [40] conducted an eye tracking experiment on two groups of human volunteers and orangutans. They studied symmetry with different level of complexity while recording the visual scanning pattern for aesthetic evaluation from human groups. They found from fixation pattern that human prefer well-organized compositions. In the field of the web design, Leuthold et al. [41] measured the effect of task complexity on different Web navigation system and found the higher perceptual value in case of vertical menus. Similarly, Goldberg [42] studied the effect of several page design factors through eye tracking and measured the complexity of the Web page. In another eye tracking experiment [43], user's attention and behavior were studied in the presence of varying cognitive loads. It was found that visual attention affected moderately by the task complexity. Henderson et al. [44] performed an eye tracking memory test to measure the effect of semantic consistency. They found random fixation at the start of viewing the complex scene and this was not associated with semantic consistency. Wallraven [17] analyzed both perceptual and eye tracking data of different paintings and defined some of the properties of bottom-up aesthetic experience. From the data of fixation duration, they found that both aesthetic viewing and complexity determination followed the global search strategy.

33.4.2 Composition of Visuals and Its Association with Eye Tracking Variables

Molnar [26] explained that a good composition consists of a combination of collative properties and semantic information. There are several models that provide the effect of image composition on aesthetic experience. From the time of ancient Greek civilization, rules for geometric composition existed and thrived during the time of Renessa (golden ratio, golden rectangle). Studying visual exploration through eye tracking can reveal the perception of compositional features of the stimuli during an aesthetic experience. Thus, the influence of compositional features on the pattern of eye movements is very important to measure the aesthetic experience.

In a good composition, visual elements remain organized in such a way that their perceptual forces interact with each other to evoke semantic as well as attentional values to the subject. During the initial visual exploration of the stimuli, the viewer uses short fixations to identify the structural features of a composition. After that during the detailed analysis of compositional structure longer fixation duration was observed. During the diversive exploration, the semantic meaning of the compositional structures is interpreted [12]. Nodine and Mcginnis [45] did an eye tracking experiment on a compositional balance of the painting. They have deliberately made some structural changes with original painting and recorded eye fixation. They found that modification in composition clearly changes the viewing time of the painting which is related to the attention and thus affects the perception of the subject. They found that starting fixations were successfully guiding attention, while fixation distribution for the visual exploratory patterns of both original and modified painting followed the balance line providing the directionality to the visual exploration. A similar experiment was carried out by Locher and Nodine [46] to study the different type of visual exploratory behavior to measure the symmetry effect. In that experiment, visual samples were prepared with a different compositional feature by varying the symmetrical level of same paintings. They found that by changing the compositional symmetry of stimuli, diversive exploration of the pattern got affected but there was no impact on the specific exploration. This proved that specific exploration doesn't have any effect on the perception.

There are also eye tracking studies that demonstrate the perceptual difference of visual composition between the art trained and untrained subject. Nodine et al. [47] studied the subject's visual exploration pattern during execution of composition judgment. They found that composition affect the attention of the trained viewer but untrained viewer's attention was significantly less due to the less understanding of compositional symmetry in the stimuli. Locher [31] has discussed the effect of the center in a composition of stimuli. He classified the center of the stimuli into three types: perceived balance center (compositional center), geometrical center, and visual gaze center. He explained that none of the centers is actual center of the stimuli. To test this central compositional exploration, Nodine [48] asked the subjects to stare the extreme left corner of the stimuli at the beginning of experiment but when the experiment started within three-second subjects' vision were shifted to the center of the stimuli. From the literature, it is observed that central area of visual stimuli is involved in perception attraction as the gaze density is found to be densely distributed in the central region.

33.5 Conclusion

In previous sections, various research works have been cited to demonstrate the validated findings related to the use of eye tracking. Also, this review has represented visual scanning behavior during aesthetic experience with special reference to bottom-up information flow during visual perception. A different aspect of the bottom-up process with its cognitive functioning has been illustrated to explain how composition and complexity of a visual, affect the aesthetic experience. Some of the psychological and neurological models have also been mentioned with their relevant implications. The current extensive literature review revealed that still there is no model which can explain all aspects of aesthetic experience from the perspective of philosophy, psychology, and neurology. Due to lack of holistic approach to both subjective and objective evaluation of visual aesthetics, there are no defined measures for aesthetic experience.

From the perspective of design research, stimuli (e.g., product/visuals/artwork) preparation is the most crucial step. Stimuli should be designed in such a manner that these hold the appropriate level of complexity and suitable quality of composition. This type of stimuli would be beneficial to drag a certain level of visual attention required for aesthetics perception. Complexity level of too high or too less would not be effective to hold the attention of the subject. On the contrary, the better quality of composition would help in attracting more visual attention. Aesthetic experience is a mixture of both top-down and bottom-up information flow. As far as the stimuli design is concerned, there is no difference in the top-down and bottom-up information flow during the aesthetic experience. The literature on cognitive information flow suggests that aesthetic experience of "classical painting" can be better judged than "abstract painting" by the use of eye tracking technology. During visualization (free viewing) of abstract paintings, most of the information flow is in top-down fashion but in classical paintings, the information flows is in a bottom-up manner. This might happen due to the explorative phenomena (specific and diverse) of the human eye to acquire information.

From the findings of literature review, it can be concluded that the measures of aesthetic experience, e.g., the level of complexity and quality of the composition might be quantitatively assessed in terms of degree of visual attention using eye tracking technique. Thus, the future scope of research includes the establishment of the relationship between the eye tracking variables and different variables of aforesaid measures of aesthetics through evidence of empirical research.

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Part V
Human Factors in Design (Physical and Cognitive Ergonomics; Design for Emotions, Etc.)

Chapter 34
Interface Design of Low-Cost Collision Alerting System for Sports Aviation

Anshuman Karmakar, Braj Bhushan, Christoph Santel, Ahmed Sameer and Bishakh Bhattacharya

Abstract The objective of this study was to test the efficacy of a new traffic display compared to an existing display used for sports aviation in identifying aircraft in the outside surrounding. The study was conducted on 30 novices to test whether the visual and interactive properties of the new display is effective in detecting other aircraft. Two videos of flight simulation were generated using Microsoft Flight Simulator and presented on Tobii eye tracker. The participants had to indicate the three-dimensional position of the other aircraft based on the visual display. ANOVA was conducted with the viewing area (cockpit and sky) as within-subject variable and display (new and existing) as between subject variable. Findings suggest that the accuracy of the participants was marginally better with the new display compared to the existing one. This work can be helpful in designing low-cost devices for identifying aircraft in the outside surrounding.

Abbreviation

AOI	Area of interest
CAS	Collision alerting system
FLARM	A low-cost flight alarm system
GAFTD	General aviation flight training device
HMI	Human–machine interface
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
IVT	In-vehicle technologies
MAC	Mid-air collision
OTW	Out-of-the-window
TFD	Total fixation duration
VFR	Visual flight rules

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34.1 Objective

While most commercial air transport is operated under instrument flight rules (IFR), visual flight rules (VFR) are predominantly used in many general aviation operations [4]. IFR flights are usually separated from one another by means of clearances and instructions issued by air traffic control. If IFR flights nevertheless end up on a collision trajectory, the airborne collision avoidance system is often available as a last line of defence.

Contrary to IFR flights, for most VFR flights separation assurance from other traffic is the sole responsibility of the pilot [5]. In order to successfully separate in this case, pilots must detect traffic visually and manoeuvre their aircraft to avoid the traffic, if necessary. This procedure is known as the see and avoid principle. However, see and avoid is a non-deterministic process which cannot reliably avoid all collisions. Some conflict geometries provide inadequate physical stimuli for the pilot to recognize the collision threat as such, even if the conflicting traffic is "in plain sight" [9]. In these cases, see and avoid fails as a means of reliably avoiding a mid-air collision (MAC).

Collision alerting systems (CASs) are a way of supporting general aviation pilots in their task of seeing and avoiding other traffic. Quasi all of these systems intended for general aviation are cooperative, requiring participating aircraft to be equipped with compatible technology.

While designing a CAS, special attention must be paid to the design of the human–machine interface (HMI). It is the part of a system which helps the pilot determine "what needs to be done" ([12], p. 185) to prevent a collision. However, oftentimes information on HMIs is coded according to social convention, which may vary between cultures. In a market study of such systems performed by Santel ([8], Chap. 3), it became apparent that most CASs and their HMIs for light aircraft so far were developed in Europe or North America. However, the deregulation of aviation legislature in Asia and the associated spur in general aviation VFR flights result in increasing research and development activity regarding CASs there [7]. Thus, the following research question arises: How should an HMI for a light aircraft CAS targeted at one of these emerging markets look like?

34.2 Background

Some HMIs employed in general aviation CASs do not display their data unambiguously. Accident investigators see this ambiguity as a contributing cause in multiple mid-air collisions (MACs). Driven by these findings, Santel [8] investigated how graphical presentation formats of traffic information interact with the usability of CASs in general aviation. He showed that all dimensions of usability—effectivity, efficiency and subjective user satisfaction—can be optimized by applying a user-centred design process and involving general aviation pilots early on in this process.

User-centred design has been successfully applied to other aviation domains, such as air traffic control officer workstations [6]. While some may argue that aviation personnel usually receive training on the systems they use, and that the potential for increasing user efficiency through user-centred design is limited, this criticism does not apply to general aviation CASs. Santel [8] has identified that training on collision alerting systems is currently not a part of standard flight training curricula. This may leave gaps in the mental models of between how a CAS actually works and how the flight crew assumes it to work. It is exactly this gap that user-centred design attempts to close by providing methods for identifying mismatches between the assumed and actual behaviour of the system early in the design process. Potential users do not even need to be in a position to verbalize their assumptions on how the system works. Instead, by analysing how a potential user interacts with the system, one can identify these assumptions from non-verbal behavioural data.

Besides the mentioned work, we are unaware of major research contributions to the use case of HMI design for general aviation CASs. Also, we could not find such an HMI having been specifically designed for the emerging markets in Asia. In this context, the work presented in this paper can be seen as a first design iteration in a user-centred design process with the goal of developing a HMI for general aviation CASs targeted for the emerging markets.

Within the research for this paper, a new interface was designed. First, a need statement was established after discussing with stakeholders. Then user research was conducted to find out (a) the pain points of pilots in different flying scenarios, (b) aspects/advantages/effectiveness of different instruments available in typical sport aviation flight cockpits. User research was done by preparing questionnaires, sending them to professional pilots with flying experiences and documenting the results/answers provided by the professional pilots. After that, competitor analysis was done to set benchmark for new design. Thereafter several design concepts were implemented and tested with users and stakeholders and then analysed for enhancement. The final design was identified after few iterations.

The final design indicated horizontal angular directions in o'clock values and the horizontal scale showed upper and lower parts. The front direction was represented by upper scale from 9 o'clock to 3 o'clock, whereas the lower scale was from 4 o'clock to 8 o'clock representing backward direction. The reason for representing horizontal angular directions in o'clock values is the popularity of such language used for communication between co-pilots, which is one of the findings of the user research. Further, a line connected middle of the object to the clock's position, working like an hour needle of a clock, indicating the horizontal angular position. The width of the object was inversely proportional to the horizontal distance. Further, distance resulting into possible mid-air collision was also indicated by four different colours where each colour represented the degree of alarm level. The final design was thought to be more intuitive by the pilots. Visual data of the new display was also endorsed "useful" by the non-pilot participants.

Figure 34.1 compares the (a) new design of the interface and (b) exiting FLARM display. (a) The new design represents the horizontal position by connecting the

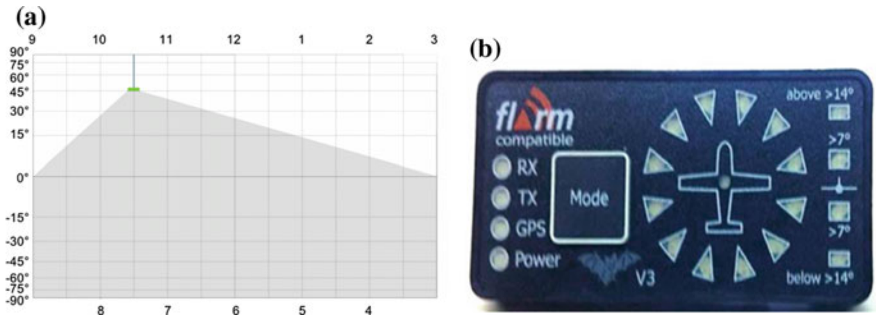

Fig. 34.1 Interface of low-cost collision alerting system. **a** New Interface design and **b** existing FLARM display

needle (blue line) to the o'clock scale on *X*-axis, vertical position by angle on *Y*-axis (0° represents the horizontal surface of pilot's own aircraft), distance by width and colour of the object (green for safe distance, same represented in Fig. 34.1a, red for dangerously close distance, and yellow and amber for in-between stages). (b) The existing FLARM display represents horizontal position by lighting one of the 12 LEDs circulating a top view image of an aircraft, vertical position by lighting one of the 4 LEDs which indicates above or below 7° or 14° of pilot's own aircraft horizontal surface. The major changes in new design compared to existing FLARM display are (i) showing a front view instead of a top view, because generally cockpit instruments are vertically or semi-vertically installed, so display will be in front of the pilot, (ii) horizontal position in o'clock scale, whereas no scale is used in FLARM display, because that is a common communication language between co-pilots, (iii) distance is represented with size of the object appearing on display which is not represented in FLARM display at all, (iv) use of colour to represent risk with a very global pattern of colour usage.

Having developed a new egocentric display following iterative process, we experimentally checked the efficacy level of the new display. For this purpose, the new interface design and the *FLARM* display of *FLARM*® *Technology* [2], an existing traffic indicator model, were embedded in two separate videos of flight simulation. *FLARM* display is supposed to assist the pilots in making judgments and thus reduce the threat of MACs. The new design was expected to do the same. Thus, the primary objective of this study was to test the efficacy of the newly designed display against the existing *FLARM* display in terms of identifying the other aircraft in the outside surrounding.

Wickens et al. (2003) observed that the probability of attending to an area of interest (AOI) is a function of the value of all tasks that the AOI supports. Although study of visual scanning of novices in aviation is sparse, visual scanning in roadways drivers and novices suggest extensive scanning by experienced drivers inasmuch as they exactly knew where to expect or search relevant driving information [11]. As flight training involves a large number of novices, empirical exploration of in-flight visual scanning of novices for search of salient information is extremely important. Therefore, we investigated visual scanning of novices wherein attention to AOIs was tested using an eye tracker.

Studies have found that when people find relevant information from a specific channel or if the information frequently appears in the area of interest they start attending more to it [10]. Wickens et al. [13] found that pilots in a general aviation flight simulator attended to the outside world for about 37% of their time.

Chun and Jiang [1] have argued that the attention system demands prioritization of significant aspects of complex visual scenes on the basis of behavioural relevance. Given the fact that the in-flight display system has several displays to assist the pilot, it is important to examine how the area of interest (AOI) is decided in a multi-element display. Moreover, the task load such displays cause for attention is of relevance.

The present study explored the difference in visual scanning using information from an in-vehicle technology (IVT), i.e. the two displays. It also attempted to examine participants' performance and visual scanning with respect to the information from IVT. The attempt was to see if the new design could help the participants (non-pilots in the present study) to detect another aircraft on a conflicting path so that they could avoid a possible collision. It was hypothesized that (i) the time spent looking inside the cockpit should be less than the time spent looking at the outside surroundings (in this case, the inside of cockpit is the lower half of the screen depicting cockpit area and the outside surrounding is the upper half of the screen depicting sky area), and (ii) in similar traffic situations, the visual and interactive properties of the new interface design should be considerably supportive in detecting other aircraft.

34.3 Method

34.3.1 Participants

The study was conducted on 30 novices (26 males and 4 females) from middle socio-economic background pursuing Master of Technology degree in India. They were novices without any flying experience. Because of lack of opportunity to hire professional sport aviation pilots, the experiments were conducted with novice participants only. The mean age of the participants was 25.97 years (SD 3.46 years). The participants were divided into two groups of 2 female and 13 male participants each. One group was exposed to the new traffic display and the other group to the existing display. Participants with any vision impairment or those on medication were excluded from the study.

34.3.2 Procedure

This research was approved by the Institutional Ethics Committee at IIT Kanpur, and informed consent was obtained from each participant. Two videos of flight simulation were generated using Microsoft Flight Simulator. Both the videos showed a cockpit control panel area at the bottom half and open sky on the upper half of the 23” monitor with a resolution of 1920 $\times$ 1080 pixels. The open sky (upper area) was dynamic throughout the videos with embedded cockpit sound effect. Both videos were alike in all respect except that one contained the newly designed interface and the other the *FLARM* display. Both displays were placed in the same area of the cockpit instrument panel above the communication and navigation radio.

The duration of both simulated flight videos was 4 min and 37 s. Six other aircraft appeared on the upper half (sky area) in each video. The position of the other aircraft was visually indicated on the displays. These aircraft appeared four times in the front position on the screen and twice behind the aircraft. The experiment was conducted using a T*obii* TX 300 eye tracker. A five-point calibration was done for every participant. The participants sat on a chair at a distance of 65 cm from the monitor. The area between the chair and the screen was covered with white sheets to create an ambiance of a cockpit and also exclude other visual distractions. It also helped the participants to look only at the monitor as other visual distractions were excluded. The participants were instructed to assume themselves sitting in a cockpit and piloting a sports aircraft. They were told that the lower half of the screen showed different cockpit instruments along with a traffic display indicating the position of other flying objects in the sky with respect to their own aircraft. They were asked to verbally state the three-dimensional position of the other aircraft in the air (front or back, up or down and left or right). The data was collected after each participant had completed practice trials.

34.4 Results

The broad objective of this study was to design a display for low-cost collision alerting systems that adequately address design aspects of human–machine interaction raised in the previous studies [8]. The study compared a new traffic display against an existing solution. The primary objective of this study was to examine participants’ viewing time distribution between the control panel (cockpit) and surrounding (sky) to see if participants spend significantly more time looking at the sky than the cockpit. To achieve the objectives, two hypotheses were tested.

Viewing time distribution between cockpit and sky: it was hypothesized that the time spent looking inside the cockpit would be less than the time spent looking at outside surroundings, and the participants would focus more on outside surroundings than the cockpit (the inside of cockpit is the lower half of the screen

Table 34.1 Summary statistics for total fixation duration (TFD) in milliseconds

View area	Display	Mean	SD
Cockpit	New	52.53	24.07
	FLARM	56.49	23.30
Sky	New	46.56	35.74
	FLARM	54.41	42.62

depicting cockpit area and the outside surrounding is the upper half of the screen depicting sky area). In order to test the hypothesis, a mixed-factor analysis of variance was conducted to compare the gaze behaviour of the participants with the viewing area (cockpit and sky) as within-subject variable and display (new and existing) as between-subjects' variable. Total fixation duration (TFD) served as dependent variable. Table 34.1 summarizes the statistics for gaze behaviour (TFD) of the participants.

The table summarizes participants' gaze behaviour: the mean and standard deviation of TFD at cockpit and sky (lower half and upper half of the screen) separately for the two videos (with new and existing displays)

Neither the viewing area nor the display influence the TFD significantly; $F(1,28) = 0.21, p = 0.65$ for viewing area; $F(1,28) = 0.27, p = 0.61$ for display. This leads us to reject the first hypothesis that participants spent more time viewing the surroundings (upper half of the screen) than the cockpit (lower half of the screen) for both of the videos (with new interface and with FLARM display).

Participants' performance with both displays: one of the tasks of the participants was to verbally indicate the three-dimensional position of six other aircraft on the basis of display. Although the accuracy of the participants is better with new display in all six simulations, the difference was not significant. This could possibly be because of small number of trials in each simulation which would have led to ceiling effect.

Figure 34.2 shows gaze behaviour of the participants' during the experiment. Figure 34.2a, b shows gaze pattern (fixations) while using the existing display before and after the other aircraft appeared in the sky, whereas Fig. 34.2c shows gaze behaviour while looking at the open sky in the area of expectation of the aircraft. Figure 34.2d shows the gaze behaviour while using the new display once the other aircraft appeared in the sky. Each coloured circle represents individual participant's point of fixation on the screen. It is obvious that the participants fixated closer to the later appearance of the aircraft, thus endorsing the efficacy of the newly designed user interface of low-cost collision alerting system.

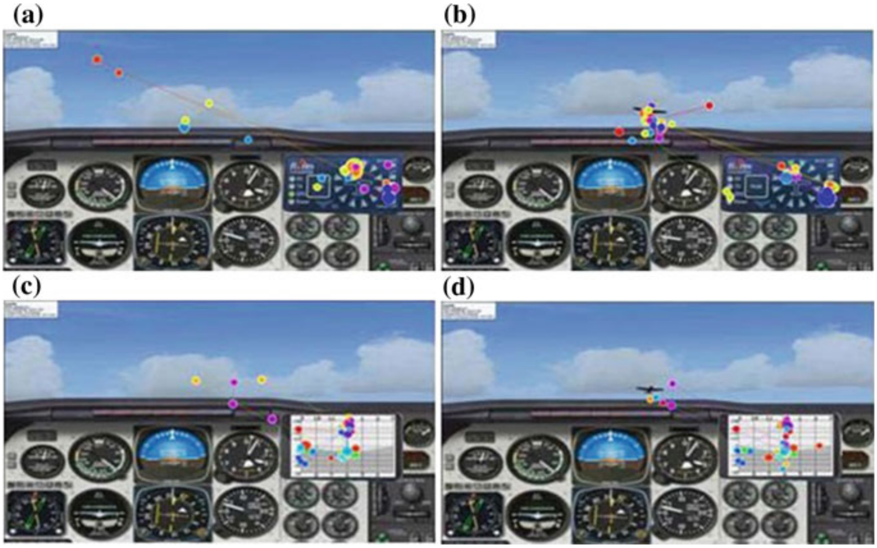

Fig. 34.2 Gaze pattern (fixations): each coloured circle represents a gaze fixation. The area of the circle is directly proportional to the duration of fixation. Colour of the circles is different for each participant. **a** Participants' fixation on expected appearance of object using existing display, **b** participants' fixation on aircraft using existing display, **c** participants' fixation on expected appearance of object using new display, **d** participants' fixation on aircraft using new display

34.5 Discussion

This study revealed that viewing behaviour did not change significantly between either of the displays. Nevertheless, the new display seems to facilitate the search for other aircraft. The verbal response of the participants indicating the three-dimensional position of the foreign aircraft on the basis of display showed little increase in the correct identification with the new display. This suggests a minor advantage of the new display.

The study had, however, some limitations. It used a low-cost desktop simulation with limited field of view instead of a high-fidelity flight simulator, thus limiting generalization of findings to a true flight environment. The participant only viewed pre-recorded videos and identified aircraft location instead of doing this in conjunction with normal flight tasks. The participants were novices, and lack of opportunity to conduct the same experiments with professional sport aviation pilots as participants limits the findings of the experiments.

This study evaluated the efficacy of the newly designed UI as compared to *FLARM* display. It does contribute in establishing Euro versus Asian design of interfaces. It also contributes towards establishing an effective method of user testing, hence contributing towards design process to enhance cockpit instruments. Future research comparing novices and pilots may shed more light on the visual scanning pattern after training and experience.

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Chapter 35
A Study on the Anthropometry of the Hira Community of Assam: Its Use in Redesigning a Pottery Wheel

Bibhuti Ranjan Bhattacharjya and Sashindra Kumar Kakoty

Abstract In the study, 15 anthropometric dimensions of the female members of the Hira community are surveyed. Measured anthropometric dimensions are: standing position—weight, stature, vertical reach, eye height and arm reach from the wall and span; sitting posture—sitting height, popliteal height, knee height, elbow rest height, coronoid fossa to hand length, buttock-knee length, hip breadth and functional leg length. Anthropometric indices, namely relative sitting height (RSH), body surface area (BSA) and body mass index (BMI) are calculated. Sample population's men age and body weight are found to be 38.85 $\pm$ 11.99 year and 45.97 $\pm$ 10.53 kg, respectively. Mean stature is 151.98 $\pm$ 5.83 cm. Correlation coefficient among different anthropometric dimensions is calculated. The results depict a high correlation among different anthropometric dimensions. The highest correlation is found between stature and vertical reach (0.92). Finally, an attempt is made to illustrate the use of such data in designing equipment for pottery industry of Assam.

35.1 Introduction

The anthropometric data plays a vital role in designing appropriate tools/machinery to obtain a good fit of man–machine interaction [14]. Such data is necessary for proper matching of machine requirements with operational capabilities to enhance safety, productivity, efficiency and reduce muscular disorder of farmers/artisans [2, 5, 10, 15]. However, traditionally very little attention is given in application of anthropometric data for designing tools/machinery for rural farmers/artisans in developing nations [8, 15]. One of the basic reasons for such negligence is the

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scarcity of anthropometric data of such population [7, 13] which results in workplace injury, operational strains and poor efficiency [10, 15].

The population of the northeastern part of India belongs to the communities/ tribes which are the origin of diverse stocks and ethnic background. Hence, the anthropometric data of such groups have wide variations [2]. Dewangan et al. [2] collected 33 anthropometric measurements from two hundred and eighty male farmers belonging to seven states of the northeastern part of India in the age group of 20–30 years. The study reveals that the anthropometric data of male farm workers of the region is smaller compared to those of other ethnic groups from countries, namely China, Japan, Taiwan, Korea, Germany, Britain and the USA.

Dewangan et al. [3] reported anthropometric data of female agricultural workers of two northeastern states, namely Arunachal Pradesh and Mizoram. The study collected and examined the anthropometric data of three tribes from Arunachal Pradesh and one tribe from Mizoram [4]. Adi, Apatani and Nishi tribes from Arunachal Pradesh and Mizo tribe from Mizoram was considered for the study. They measured seventy-six body dimensions from a sample of eight hundred and one male agricultural workers. Patel et al. [10] collected anthropometric dimensions of one hundred and thirty male agricultural workers from Kamrup district of Assam, India. They compared the result with anthropometric data of other parts of India. The studies reveal that there is a variation of anthropometric data among the different parts of the country [14]. Such variation exists among the tribes/communities of the region.

Most of the anthropometric studies carried out in the northeastern part of India are related to the agricultural workers. The available literature indicates that non-farm workers are neglected in most such studies. For example, no anthropometric data of the Hira community of Assam is available in the literature. The Hira Community belongs to the scheduled caste (SC) category in Assam, India. They are exclusively engaged in making traditional handmade pottery for their livelihood [8]. As per census data 2001, the population of Hira community in Assam is 55,106, which is accounted for 3% of the state's scheduled caste population [9]. Around 1.8 million families [12] are associated with pottery works in the state. Unfortunately, technology intervention in the pottery sector is almost nil, and artisans are still using age-old traditional tools. Such hand tools are being used for ages, which is not ergonomically correct. Hence, there is an urgent need of ergonomic intervention in the sector to design tools/machinery in line with ergonomic principles. Keeping in mind all the factors, the study is intended to collect and analyze the anthropometric data of the Hira community from Assam. Finally, an example is presented to illustrate the application of collected anthropometric data in the process of redesign of a pottery wheel.

35.2 Method

Two districts of Assam, namely Kamrup and Nalbari were selected to collect anthropometric data of female members of the Hira community. Preference is given for artisans who are associated with pottery works. Data was collected from sixty female members of aged between 18 and 60 years from 10 different villages of the two districts of Assam. Village heads are informed about the study before the survey is started. The detailed procedure of the survey, application of collected data and the role of the subjects are explained to the village heads as well as subjects. The necessary arrangement was done to safeguard the secrecy of the subjects. Subjects' health is examined. Subjects of good health and physically fit are considered for the study. To minimize error, subjects were asked to dress light clothes.

Fifteen body dimensions are considered for the study from previous studies carried out by [2–4]. Age and body weight of the subjects are also reported in the study. The standard procedure for anthropometric data collection as recommended by the "*conference on standardization of anthropometric techniques and terminologies*" [6, 10] is followed here. The dimensions considered here for study are: standing position—weight, stature, vertical reach, eye height, arm reach from the wall and span; in the sitting posture—sitting height, popliteal height, knee height, elbow rest height, coronoid fossa to hand length, buttock-knee length, hip breadth, functional leg length. In addition, three other anthropometric indices, viz.: RSH, BSA and BMI are calculated.

The body dimensions are measured using the commercially available Anthropometer. To measure weight, a portable weighing scale of range 0–125 kg is used. Anthropometer is calibrated periodically to reduce measuring error. During the measurement, the scale of the weight measuring machine is calibrated to the weights of 10–125 kg. The body weight is noted to the nearest 0.5 kg.

35.2.1 Data Analysis

To calculate the descriptive statistical parameters of the collected data, Microsoft Excel software is extensively used. First, the outliers and arbitrary data are identified and excluded carefully to minimize the human errors. In the study, following statistical values are measured: minimum, maximum, mean, SD, CV, percentile (5th, 50th and 95th), RSH, BSA and BMI. The correlation coefficients (r) between different anthropometric dimensions were calculated to examine the extent to which different anthropometric measurements are correlated with each other. To check the normality of the collected data, skewness and kurtosis values are calculated. Finally, regression analysis is performed to estimate the body dimensions.

35.3 Results and Discussions

Table 35.1 gives the descriptive statistics of all the measured anthropometric measurements. Sample population's men age and body weight are found to be 38.85 ± 11.99 year and 45.97 ± 10.53 kg, respectively. Mean stature is 151.98 ± 5.83 cm. The CV value of few anthropometric dimensions, namely elbow rest height, hip breadth, age, weight BSA and BMI is relatively high (greater than 10). The value of skewness and kurtosis is found to relatively higher for following body dimensions: weight, coronoid fossa to hand length, hip breadth, BSA and BMI. The same is reported in Table 35.1.

The distribution of BMI value of the sample population is presented in Table 35.2. The results indicate that around 36.66% of the total sample population are under the underweight category having BMI less than 18.5. Out of 60 members, 34, i.e. around 56.67% of the total sample population are found to be under the normal category having BMI 18.5–24.9. A negligible portion of the sample population is found to be under overweight and obesity category.

Correlation coefficient among different anthropometric dimensions is presented in Table 35.3. The results depict a high correlation (i.e. $r > 0.7$) among different anthropometric dimensions. The stature and vertical reach are found to have the highest correlation (0.92). The stature has higher correlation with anthropometric dimensions, namely eye height (0.81), span (0.80), sitting height (0.70) and functional leg length (0.71). Higher correlation is present among vertical reach and span (0.84); vertical reach and eye height (0.78); vertical reach and sitting knee height (0.75). Although most of the computed correlation coefficients were of positive value, span—elbow rest height, knee height—hip breadth was negatively correlated. Level of significance for each dimension is tested for 1, 5 and 10% level of significance. Level of significance is indicated with star marks against each dimension. Those which are found to be not statistically significant are written without any star mark against it.

Linear regression analysis is done to check the relationship between stature and other anthropometric dimensions, where stature is considered as the independent variable. Only those anthropometric dimensions are considered for linear regression analysis for whom r value is found greater than 0.5 [11]. The summary of the regression analysis is presented in Table 35.4.

The anthropometric data of the female members of the Hira community of Assam is compared with anthropometric data of female members of two neighbouring states, viz.: Arunachal Pradesh and Mizoram collected by Dewangan et al. [3]. A comparative statement is presented in Table 35.5. The results show that there is a variation of anthropometric data among neighbouring states of the country. A Difference of more than 1 cm is observed in dimensions, viz.: stature, vertical reach, arm reach from the wall, sitting height, coronoid fossa to hand length, hip breadth and functional leg length.

Table 35.1 Summary of anthropometric dimensions of female Hira community members

	M_1	M_2	μ	SD	CV (%)	Percentile			Skewness	Kurtosis
						P_5	P_{50}	P_{95}		
Standing measurements:										
Weight (Kg)	30	97	45.97	10.53	22.92	34.95	45	65.05	2.22	8.75
Stature	139	167.1	151.98	5.83	3.84	142.59	151.75	159.91	0.67	−0.19
Vertical reach	172.4	209.3	192.25	7.77	4.04	179.04	192.4	203.4	−0.36	0.21
Eye height	118.5	153.9	142	6.18	4.35	132.6	141.85	151.72	−0.78	2.29
Arm reach from the wall	66.3	84.4	75.42	4.18	5.54	68.67	75.00	83.33	0.24	−0.14
Span	139.5	171	153.47	6.9	4.5	141.98	154.15	164.11	0.29	0.45
Sitting measurements:										
Height	68	86.2	78.89	3.72	4.71	72.38	79.1	83.55	−0.45	0.10
Popliteal height	31.20	43.50	37.97	2.32	6.09	34.20	38.00	42.33	−0.12	0.35
Knee height	36.2	57.2	45.87	3.79	8.21	37.99	46.05	51	−0.09	1.66
Elbow rest height	15.2	32.8	22.51	3.32	14.78	18	22.65	26.745	0.56	0.97
Coronoid Fossa to hand length	23	43.2	35.9	3.04	8.47	32.15	36.15	39.635	−1.12	5.30
Buttock-knee length	40	67.4	51.33	4.22	8.22	45.85	51.1	57.21	0.54	3.03
Hip breadth	25.1	46	32.85	4.95	15.08	26.98	31.7	44.75	1.25	1.21
Functional leg length	70.3	101	87.8	6.26	7.14	79.69	87.6	98.08	0.01	−0.04
Age (Year)	18	60	38.85	11.99	30.86	19	40	55.25	−0.19	−0.90
Indices:										
RSH	0.45	0.56	0.52	0.01	3.38	0.48	0.52	0.54	−0.87	2.47
BSA, m^2	1.11	2.06	1.38	0.163	11.75	1.18	1.39	1.68	1.36	4.25
BMI, kg/m^2	13.24	38.81	19.83	3.95	19.92	15.53	19.13	25.88	2.15	8.25

The unit of the dimensions is in cm, otherwise it is mentioned. M_1 = minimum; M_2 = maximum; μ = mean; SD = standard deviation; CV = coefficient of variation; P_5 = 5th percentile; P_{50} = 50th percentile; P_{95} = 95th percentile

Table 35.2 Summary of BMI of female Hira community members

Particulars	Body mass index value (kg/m^2)	Number of subjects	Percentage
Underweight	<18.5	22	36.67
Normal weight	18.5–24.9	34	56.67
Overweight	25–29.9	3	0.05
Obesity	>=30	1	0.02

35.4 Application of Collected Data in Pottery Sector

To explain the importance of anthropometric data, a case from pottery sector is reported here. In the pottery making, clay and water are mixed first. It is then moulded into the desired shape using a wooden pottery wheel. However, this traditional process of moulding is hazardous to health. As a result, health-related issues are reported. To rectify the process, IIT Kharagpur developed a pottery wheel for both male and female artisans. The same machine was extensively tested in different parts of Assam, India. The field testing result indicates the importance of redesigning the machine to make it user-friendly for local artisans. Redesigning the machine as per ergonomic principles and use of anthropometric data of local artisans will make it user-friendly and ergonomically correct for local users.

The study suggests for the modification of the following dimensions of the machine to accommodate the local artisans' anthropometric dimensions: seat height and work surface height.

Seat height: The seat height of the existing machine is 71 cm. The seat height as proposed by Choobinech et al. [1] should be popliteal height + 15 cm.

In the study, the popliteal height is found as for 5th percentile: 34.20 cm; for 95th percentile: 42.33 cm. Hence, seat height 5th percentile: 49.20 cm and seat height 95th percentile: 57.33 cm.

A seat with provision to adjust the height in the range of 49 cm to 58 cm is found to be satisfactory.

Work surface height: The work surface height of the existing machine is 91 cm. The work surface height as proposed by Choobinech et al. [1] should be seat height + elbow rest height + 20 cm. In the study, the elbow rest height is found as for 5th percentile: 18 cm; for 95th percentile: 26.75 cm.

Hence, work surface height 5th percentile: 49.20 + 18 + 20 = 87.20 cm and work surface height 95th percentile: 57.33 + 26.75 + 20 = 104.08 cm.

The study reveals that work surface with provision to adjust the height in the range of 87–105 cm is considered to be useful for the local artisans.

Finally, an attempt is made to illustrate the use of such data in designing equipment for pottery industry of Assam. In this particular equipment, the seat height and work

Table 35.3 *r* value against different anthropometric dimensions

	Stature	Vertical reach	Eye height	Arm reach from the wall	Span	Sitting height	Knee height	Elbow rest height	Coronoid fossa to hand length	Buttock-knee length	Hip breadth	Functional leg length
Stature	1											
Vertical reach	0.92***	1										
Eye height	0.81***	0.78***	1									
Arm reach from the wall	0.36**	0.4***	0.3**	1								
Span	0.80***	0.84***	0.69***	0.56***	1							
Sitting Height	0.70***	0.56***	0.5***	0.24**	0.51***	1						
Sitting Knee height	0.68***	0.75***	0.57***	0.28**	0.53***	0.3**	1					
Elbow rest height	0.09	0.19	0.04	0.23	−0.04	0.2	0.01	1				
Coronoid fossa to hand length	0.39**	0.38**	0.3**	0.23*	0.52***	0.17	0.06	−0.29**	1			
Buttock-knee length	0.49***	0.5***	0.34***	0.3**	0.51***	0.45***	0.22*	0.11	0.3**	1		
Hip breadth	0.08	0.03	0.16	0.19	0.21	0.2	−0.21	0.01	0.24	0.47	1	
Functional leg length	0.71***	0.64***	0.59***	0.28**	0.67***	0.62***	0.39***	0.2	0.34***	0.44***	0.25**	1

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$

Table 35.4 Result of linear regression analysis

Equations	F	R^2	Standard error
Vertical reach = stature × 1.23 + 5.52	329.60***	0.85	3.03
Eye height = stature × 0.58 + 11.78	109.47***	0.65	3.67
Span = stature × 0.95 + 9.87	102.03***	0.64	4.19
Sitting height = stature × 0.44 + 11.57	54.18***	0.48	2.70
Sitting knee height = stature × 0.44 − 20.93	48.68***	0.46	2.82
Functional leg length = stature × 0.77 − 28.63	60.22***	0.51	4.4

***Significant ($p < 0.01$)

Table 35.5 Comparison of mean value of anthropometric dimensions of the Hira community with anthropometric data of neighbouring states

Sl. No.	Body dimensions	Present study	Study performed by Dewangan et al. [3]	Difference
Standing measurements:				
1	Stature	151.98	153.25	1.27
2	Vertical reach	192.25	190.24	2.01
3	Eye height	142	141.76	0.24
4	Arm Reach from the wall	75.42	73.12	2.30
5	Span	153.47	153.06	0.41
Sitting measurement:				
6	Height	78.89	80.28	1.39
7	Popliteal height	35.31	37.97	2.60
8	Knee height	45.87	45.27	0.67
9	Elbow rest height	22.51	23.39	0.88
10	Coronoid Fossa to hand length	35.9	34.30	1.6
11	Buttock-knee length	51.33	50.51	0.82
12	Hip breadth	32.85	31.2	1.65
13	Functional leg length	87.8	90.02	2.22

#Dimensions are in cm

surface height dimensions are decided based on collected data (shown in Fig. 35.1). Thereby, the importance of redesigning tools/machinery has been demonstrated. However, to make the said machine ergonomically correct, modification of other dimensions is also necessary, which is in progress at IIT Guwahati.

Fig. 35.1 Pottery wheel designed by IIT Kharagpur

35.5 Conclusion

This study has reported 15 anthropometric dimensions (age and body weight included) of the female members of Hira community from Assam. The variation of anthropometric data of Hira community with anthropometric data from two neighbouring states is compared. The study indicates that variation exists between the anthropometric value of the Hira community and anthropometric data of other region and community.

Moreover, the authors suggested that the application of updated anthropometry should be considered for redesigning tools/machinery for pottery artisans of Assam, India. To illustrate the use of such data, a case of redesigning a pottery wheel is explained. Collected data is used during the modification of the dimensions of the machine. Data for 5th and 95th percentile value is considered here to cover 90% population data.

Lately, it is hereby recommended that a similar study is carried out for male pottery artisans also. The number of subjects should be increased in the future for similar studies. Besides, thorough anthropometric analysis of other community/ tribes of the state of Assam, India is necessary.

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Chapter 36
Healing by Design

Design of Public Spaces for Children's Hospitals

Rawa Abulawi, Stuart Walker and Christopher Boyko

Abstract This research focuses on four main topics: children's cognitive developments—it relates to age-appropriate interior design; children's healing environments; public spaces in hospitals—interior architecture and interior design; contextual issues—specifically the religious, ethnic and national context of Palestine. The literature indicates that research is needed in the design of healing environments for children to create spaces that are child-friendly and meet their cognitive development needs. In Palestine, qualitative data were collected during nine co-design and co-creation workshops that included arts-based activities and semi-structured interviews. Participants included children from 3 to 18 years, parents, medical staff and four groups of designers. The study uses a thematic analysis approach for analysing the qualitative data. The results of the analysis were sorted into main themes and sub-themes. The key findings of this study inform guidelines and recommendations for the design of children's hospitals, particularly public spaces in the context of Palestine.

36.1 Introduction

In this study, hospital design can provide supportive environments for healing and can take into account wellness factors for reducing stress (such as art and music). In the literature, a broad description of healing environments can be found, but it is generally understood to mean the physical and cultural atmosphere that can be designed to support patients, families and staff during hospitalisation and treatment [8]. This research

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focuses on how to provide *a supportive healing environment in terms of the interior architecture and interior design of the public spaces of children's hospitals*, which comprise the main entrance, atrium areas and thoroughfares. These areas can serve as organising elements to help people to orient themselves [19], to socialise and to way-find. The context is Palestine, which has certain cultural and religious considerations.

From the literature, there is a lack of empirical evidence that focuses on environmental considerations related to children [14]. There is only limited research that focuses on the interior architecture and design of children's hospitals [2] especially in public spaces, such as atriums; and there are gaps in the empirical evidence for creating appropriate and comfortable environments conducive to supporting healing [6]. Few studies include the preferences of children in the design of the public spaces [18]. Also, there are few studies that have discussed in detail how the medical functions in hospitals affect the design of the main entrance and atrium of children's hospitals or their relationship to supporting healing [1]. Moreover, there is a lack of consistency with respect to the functions and requirements of the interior spaces, including the supportive activities that are accommodated in the public spaces [4]; for example, some hospitals provide a play area for smaller children in the main entrance; others do not [5]. Design for children should be distinct from design for adults [16]. The spaces are be for children of different ages, and so the interior design needs to be flexible and adaptable [23]. Such needs can be translated into supportive healing spaces. Despite this, we still find health care spaces that do not address the needs of children across all ages [12]. Instead, they tend to support the views of adults or may encompass themes that are appropriate for younger children but not for adolescents. Hence, it is important to include the views of children of all ages in the design, as well those of parents, in order to develop best practice [7].

Children's hospitals should offer spaces and provide welcoming interior environments as well as facilities that accommodate children of all ages, and allow them to feel comfortable and at ease [25]. Generally, however, interior spaces are still not designed to meet the specific cognitive needs of children [21]. For instance, many Palestinian children are treated in adult hospitals that do not have a child-oriented environment conducive to healing [12]. These issues stimulated us to ask: *For a new children's hospital in Palestine—'how should the public spaces of children's hospitals (i.e. main entrance, atrium and thoroughfares) be designed so that they are conducive to healing and are suitable for all age ranges of children (i.e. 0–18 years) especially in the context of Palestine?*'. Five research objectives provided a structure for data collection (Table 36.1).

36.2 Design Process and Methods of Inquiry

This study employs *qualitative research that uses an innovative workshop format.* The forms of this participatory research design can be described as using co-design/co-creation in a workshop format with 55 participants from children aged between 3

Table 36.1 Research objectives

Research objectives	
RO. 1	Identify the most important considerations for interior design and interior architecture related to the public spaces of children's hospitals
RO. 2	Identify the functions of the public spaces in children's hospitals that affect interior design and interior architecture decisions
RO. 3	Identify the key factors in the design of public spaces within children's hospitals that can help create an appropriate interior environment for all stages of children's development
RO. 4	Identify the context-specific issues to be taken into consideration for a children's hospital in Palestine
RO. 5	Identify the factors pertaining to 'healing environments' that should be brought to bear in the design of the public spaces

Table 36.2 Data collection process

Data collection process	
Phase one:	*Sample size*
Workshops with children	18 school children: (9 males (m) and 9 females (f)), 5 children under six years: (1 m and 4f)
Workshops with parents	8 parents: (4 m and 4f)
Workshops with medical staff	9 medical staff: 3 doctors (1f and 2 m), 4 nurses (2f and 2 m), 2 staff members (f) working in admissions and reception
Phase two:	*Sample size*
Workshops with four group of designers	12 designers (7 m and 5f)
Three individual interviews	2 m civil engineers and (1 m) director of Rafidia Surgical Hospital

and 18 years, parents and medical staff. The data collection process for the primary data was divided into two phases. Details are given in Table 36.2.

Phase one: This phase focuses on three types of participants (they are arranged according to the sequence of data collection):

(i) **Workshops with school children aged 6–18 years to create drawings and 3D models**. In this phase, the choice was to work with schoolchildren rather than children who were patients in hospitals because non-medical spaces can be more accessible, thus saving time and achieving more valuable data (e.g. using drawings, modelling and visual materials). The eighteen participating schoolchildren were divided into six groups. Such issue contributed to *Piaget's theory of cognitive* development suggests that children can be divided into four stages (i.e. 0–2, 3–7, 7–11 and 11–18) and at each stage the child will have a different level of knowledge, information and understanding [9]. Research suggests that children younger than six years old need to engage their parents to establish communication with them [22]; also, they cannot conduct tasks for a very long time; they have difficulty expressing what they like or dislike; and they tend to only concentrate on one aspect of a task and neglect others [15]. The children participated in two activities:

1. *Creating drawings with children:* In this activity, I asked the children to create freestyle drawings with the following activity titles: (1) *My favourite places that make me feel safe, happy and playful*; (2) *A place where I would like to be while I'm waiting my turn* [17]. The children used A3 sheets of paper, pencils, sticky notes, scissors, crayons, stickers and collage materials. Such methods and tools are considered a suitable and enjoyable activity for children (Ibid). I then asked the children to explain their drawings and to write down their explanations. Every child had a chance to describe their drawings verbally, and I recorded their interpretations. The inclusion of the children's interpretations of their drawing in conjunction with the 3D models method [11] helped to identify new themes related to interior design and architecture of spaces for children. Such activities can contribute to understanding the requirements for the atrium.
2. *Creating 3D models*. The same groups of children also created models, which helped to further draw out their ideas, perceptions and insights that were included in the research data. These types of methods can help to create inclusive insights into the social world of children that cannot be achieved by traditional anthropological data collection methods [17]. The recorded interviews were transcribed, and an initial analysis was provided to inform the parents' workshops.

(ii) **Parent workshops and focus groups to determine their needs and those of their young children**. In these workshops, the thirteen participants were divided into three groups. An equal number of men and women were chosen; gender is an important contextual variable in this research, so a purposive sampling was to obtain similar numbers of mothers and fathers [10]. Parents participated in two activities:

1. *Creating 3D models*. Parents were provided with the same materials as the children to create 3D models. I asked parents to create a model that expressed both parents and their young children's needs to feel happy and more comfortable when they entered the hospital.
2. *Drawing a flow chart*. Parents drew a flow chart that outlined the problems they have faced when entering hospitals with their young children (0–6 years) in terms of functions, spaces, aesthetics and facilities.

(iii) **Medical staff workshops and focus groups**. There were ten participants. Eight medical staff were divided into four groups. Medical staff participated in three activities:

1. *Classifying tables*. Five tables were classified. Such tables included parents' and children's preferences regarding public spaces of

children's hospitals. The groups had a chance to arrange and classify the initial preferences in terms of interior design elements and interior architecture spaces.

2. *Drawing charts*. The medical staff were then asked to include their preferences and what they need to make them feel happy and comfortable during their work, particularly in the public spaces of children's hospitals. They created four charts.
3. *Discussion around a model that included preferences of workshops I and II*. I explained the children's and parent's needs that emerged from their respective workshops. The aims of this activity were to address any contradictions and consistencies between medical spaces and children-friendly spaces and to determine the context of child-friendly spaces within the context of the hospital.

Phase Two: This phase comprised of two types of participants:

(i) **Workshops with designers to develop ways of designing the public spaces of a children's hospital**

This phase involved workshops with four groups of designers in Palestine. These methods can strengthen the process of collecting rich perspectives from the participants and can support the input of the stakeholders through activity-based research [13]. The workshops involved 12 participants. We chose this sample size based on the available time and resources [24]. Before conducting this workshop, some initial analysis of the children's, parents' was conducted, and medical staff workshops using tables, reports and memos. The initial data were sorted according to the four groups of designers and questions identified for each group. This process helped designers understand in more depth the type of research and their role shops, and enabled them to prepare ideas about how to deal with the data to design the spaces. The findings and workshop agenda were presented in Phase 1, and questions were taken before and during the group work.

1. *Interior architecture*: This group of designers discussed the initial results of the data that emerged from the Phase 1 workshops. They drew sketches and diagrams on the A3 and A4 sheets and used hexagon cards to present their ideas about how to deal with the architectural and interior architectural elements that were highlighted by parents, medical staff and children. For example, they suggested how to determine the integration between inside and outside.
2. *Interior designers*: They followed the same process as the interior architecture group, with their ideas concentrating on interior design elements.
3. *Graphic designers*: They suggested some ideas about the concept design and materials that are available in Palestine, and the importance of connecting wayfinding signs in the entrance and atrium with the interior architecture and interior design concepts.
4. *Artists and ceramicists*. Using the hexagon cards, they jotted down their suggestions and ideas about the concept design of art, materials and how to

determine how culture in the arts can be suitable for adults and children. Also, they highlighted the importance of using children's drawings and models in the concept design of art.

(ii) **Three individual interviews**. These interviews determine the availability of appropriate materials, constraints and design considerations for the admission areas.

36.3 Data Analysis and Results

A thematic analysis approach was used to analyse the primary data [3]. The qualitative approach is incredibly diverse and complex (ibid). Such approach was used in order to deal with such complexity. The process of analysing such data is recursive; it needs to move back and forth between research data [3]. The data analysis helped to identify two major themes:

1. **Context** (i.e. culture, appropriateness of visitors area and hospitalisation, and family and friends' support).
2. **Physical environment**: **interior design and interior architecture** (i.e. medical spaces, non-medical spaces, design elements and specific items, and environmental design).

The emerging themes include participants' preferences and needs regarding those factors they considered essential for their comfort within public spaces of a children's hospital. They were presented and supported by direct quotations from the participants (see Example 1, 2). The results of children's preferences were presented according to three age ranges (i.e. 3–7, 7–11 and 11–18 years).

Example 1: *I like green, the colour of wood and water because they provide me with a feeling of majesty and they connect you with nature…*(Girl, 15–16 years) … *Using cartoon images on walls may make you feel dull. However, including nature can be appropriate for all age levels. These pictures related to fish and water on the ground make me think of Summer season, and I feel happy…*(Girl, 16–17 years). *In front of the reception desk, I put a picture from our culture to provide people with a sense of pride that they are in their country* (Girl, 13–14 years).
Example 2: *In the waiting area, there should be a television and some features related to water, an area for smoking, and non-smoking, outdoor green area, toilets, area for music that has a piano, and playing the guitar* (Father).

36.4 Findings and Discussions

The findings of this research were classified and prioritised into six groups (see Appendix). These help in identifying new knowledge and meaningful information; finding relationships in structures; reducing complexity; and seeing the object from different angles [20]. In addition, they helped to: answer the *research question and research objectives* of this study; to develop *initial recommendations* for the design of public spaces of children's hospitals; and to draw out the final *conclusions*. The criteria used to classify the findings were linked with the field research findings and literature review, as well as the perspectives of designers during the subsequent workshops. They were also related to the research aims, to research question and to the objectives of this research. Findings in relation to the research objectives were:

Regarding **Research Objective 01** (Table 36.1), findings identified two important design considerations: (1) interior architectural plans related to perceptions of preferred activities and design spaces in the public areas of a children's hospital. These design considerations encompass the importance of providing: easy access to medical and non-medical spaces; integration between outside, green areas and inside spaces; security and safety; clear wayfinding signs; environmental design considerations; supplementary spaces and facilities; and aesthetic components, and (2) specific design considerations related to age and gender preferences.

In relation to **Research Objective 02**, the research findings showed that there are two primary kinds of spaces to be considered: (1) the medical functional spaces and (2) the non-medical spaces. The relationship between these spaces requires special consideration regarding interior design and interior architecture. For example, the emergency admissions should not be placed close to the children's waiting areas; however, the emergency department should be close to the triage room. Also the findings indicated an open design concept space for non-medical spaces, and it is important to address all the potential design considerations including ventilation, lighting, and hygiene, avoiding infection, isolation of noise, aesthetics and types of materials.

Regarding **Research Objective 03**, the research findings identified five factors related to:

1. *Specific preferences of age ranges of children*. The findings showed differences and similarities across the age ranges of children.
2. *Thematic design connected to nature, telling stories, materials, and open design concept, and integration between exterior green areas and interior spaces*. The research findings identified a strong preference by all stakeholders to include nature in the design spaces (i.e. green courtyards), outdoors spaces and landscape, art, materials, etc. However, there should be a consideration relating to how children depicted nature according to their cognitive development and age-range level. Also, the findings strongly identified the provision of open design concepts, particularly for non-medical spaces to provide comfort and ease of vision, and integration between interior spaces and outdoors green areas to provide easy access between the waiting areas and the green outdoor areas. In

addition to the above issues, designers strongly recommended using storytelling in the thematic design concepts by using the children's preferences and artwork.

3. *Design according to age regarding interior architectural spaces and design elements*. For instance, different perspectives were identified regarding the division of public spaces (waiting areas, play areas, admission and reception spaces) according to children's age ranges.
4. *Home-like design*. The findings showed a strong preference from participants to include home-like design (e.g. furniture and personal toys) to provide comfortable and age-appropriate design and supportive healing environment for everyone.
5. *Various types of forms and shapes for interior design and architecture*. The findings identified a strong preference for the inclusion of circular and organic forms and shapes (i.e. for furniture, reception and admissions desks, interior design elements).
6. *Gender issues*. The research findings identified the importance of determining gender differences between children in order to provide age-appropriate design.

According to **Research Objective 04**, the research findings identified five factors related to: (1) culture (i.e. separation between genders, referencing cultural heritage and traditional architectural elements); (2) design according to age and cognitive development; (3) specific needs of particular age ranges of children; (4) gender issues; and (5) other specific elements (i.e. age appropriateness, hospitalisation, health care services).

In relation to **Research Objective 05**, the research findings incorporate the previous four objectives to recommend essential factors that contribute to the creation of a supportive healing environment in the public spaces of children's hospitals.

Based on the discussion presented in above, three types of recommendations have been developed related to design public spaces of children's hospitals:

1. **Recommendations that are essential to provide healing environment and age-appropriate design for children**. Such recommendations are contributed to the inclusion of: *aesthetics issues* (i.e. art connected to nature and culture, colours and thematic design related to nature and home-like design); *various forms and shapes* (i.e. circular, organic, smooth, gable roofs, symmetrical, l-shape and irregular forms; *attractive and appropriate wayfinding signs*); *various types of materials* (i.e. bright, textured, safe, transparent, soundproof, connected to nature and non-absorbent); *attractive and distraction elements* for children to be included at main entrance, waiting areas and registrations areas; *gender differences*, *minor* or *no* differences.
2. **Recommendations that are essential to the provision of treatment and well-being for children**: The architectural design plan for dedicated children's hospitals should include eight functional medical spaces in close proximity, on the same level as the main entrance and atrium, in order to insure they are

readily accessible, namely emergency, triage room, X-ray, laboratories for diagnosing and testing, outpatient department, pharmacy, physiotherapy and orthopaedic department.

3. **Recommendations related to the specific context of this project—Palestine**: The Palestinian authority should give serious consideration to the creation of a dedicated children's hospital in Palestine that serves the age range 0–18 years. In addition to that, it essential to provide separation between genders in the public spaces on religious and cultural grounds (i.e. complete separation between genders in the spaces designated for praying, sleeping, and in the toilet areas), partial separation in the waiting and playing areas for children over seven years of age, and complete separation between genders of children above the age of thirteen.

36.5 Conclusions

This study demonstrates that *practical design methods in the research process* can be very effective in fostering creativity and in drawing out ideas and preferences from young children and other stakeholders. Such methods provide a novel approach to the design of healing environments for children. Following this, designers should incorporate the five previous objectives (i.e. 01–05) to create the public spaces of a *new children's hospital in Palestine* (i.e. main entrance, atrium and thoroughfares), so that they are conducive to healing and are suitable to all age ranges of children (i.e. 0–18 years). Despite this, further exploration and evaluation are needed in larger studies that consider variables of this study regarding age, culture, gender and physical environment attributes to produce further layers of useful design specifications. For instance, this study did not include disabled children because of time constraints. Also, it would be more beneficial to include more people working in the reception areas to garner their insights, information and understanding about the particular functions of those areas. Furthermore, exploring and testing the findings in real-world design settings such as children's hospitals, and by triangulating this research through survey research will provide further valuable insights into how to provide a supportive healing environment, particularly in the public areas that are appropriate for all age ranges of children.

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Ethics Issue Before starting data collection, researchers acquired necessary ethics approvals from the RSO Ethics Committee at Lancaster University.

Appendix

Summary of research findings

1.	**Findings that agree with the literature review**: –Inclusion of interior design elements (i.e. attractive materials, wayfinding signs, attractive and distraction elements particularly in the main entrance, i.e. art, colours, waiting, reception, admission and registration areas, circular and organic forms and shapes –Inclusion of interior architecture design elements (i.e. play areas, various types of waiting areas—outdoor and indoor for long and short visits, easy accessible and visible, wide main entrance, provision of an open design plan for reception areas and play areas, but the design should provide semi-private, designated spaces for both genders, integration between public spaces, i.e. waiting areas, main entrance, play areas, reception or information areas, spaces for food and outdoor green areas –Environmental design issues (i.e. effective ventilation, enough light, comfortable smell and prevent noise)
2.	**Findings that partially agree with the literature review**: –Inclusion of Interior design elements (i.e., symmetrical, irregular forms and shapes, thematic design connected to nature in the waiting areas, bright colours, and inclusion of green, blue, brown, and yellow colours) –Inclusion of interior architecture design elements (i.e. traditional architectural elements connected to culture)
3.	**Findings that do not agree with the literature review**: –No gender differences between children regarding the inclusion of art connected to nature –Separation between genders in the public spaces related to play and waiting areas
4.	**Findings that show gender differences, minor or no differences**: –No gender differences between children regarding the inclusion of art connected to nature; inclusion of green, blue, brown and yellow colours –A gender differences across age range of children regarding the inclusion of abstract art, and colours, i.e. boys appreciated white, black, turquoise and orange; however, girls appreciated red, purple and pink colours –Minor differences in gender regarding the inclusion impressionistic types of art, and inclusion of organic and smooth lines and forms
5.	**Findings that are especially connected to design according to age**: –Findings that do not alter according to age: the inclusion of six types of colours, i.e. blue, green, yellow, purple, pink, brown; the inclusion of thematic design connected to nature, entertainment activities related to active/physical (i.e. football, swimming, fishing); learning (i.e. playing music); passive/solitary (i.e. watching television and aquariums, and learning music); the inclusion of soft and circular forms and shapes of furniture; the inclusion of art connected to nature, abstract, culture and music themes; the inclusion of home-like design; the inclusion of textured, bright and related to nature materials; and the inclusion of symbols –Findings that are alter according to age range: the inclusion of play areas and entertainment activities can be divided into two age ranges (i.e. 3–11 and 11–18 years) rather than four age ranges; and the inclusion of spaces for food appeared to alter with age and cognitive development
6.	**Findings that are especially related to the context of Palestine**: –Findings indicated to include art, courtyard, forms and shapes that encompass traditional elements, motifs and references to cultural heritage; and the notion of separation between genders

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Chapter 37
Evaluating Occupational Health and Safety (OHS) Issues for Craftsmen in Metal Handicrafts

Sutapa Pati

Abstract The aim of this paper is to evaluate occupational health and safety (OHS) issues faced by traditional craftsmen in bell and brass metal handicraft process in Balakati metal craft cluster of Odisha. The process of handicraft metal work, though handled in a small scale, uses hazardous industrial processes of high-temperature melting, foundry work, beating, grinding, and machining; similar to hazard prone industrial processes. Craftsmen are exposed to serious OHS and ergonomics-based hazards. Modern industrial process mapping methodology including walk-through survey was conducted for the same. Different metals may be correlated with OHS hazards (toxicity, heat stress, and fumes), route of entry (inhalation, skin contact, and ingestion) and phase of hazard. This paper fills the gap in identifying the OHS hazards and also provides recommendations for design of control strategies such as personal protective equipment and process change in line with learnings from existing industrial practice.

37.1 Introduction

The handicraft sector in India is considered the second largest employment providing sector. The number of persons associated with the sector has been continuously increasing over the years; from 23 million persons in 2002 to 65.72 million persons in 2005–2006 and 76.17 million persons in 2010–2011 [1]. India has a diverse range of craft-based sectors, such as textiles, embroidery, metal, pottery, wood-based work, gems, and jewellery-based items. These craft among others are purposed for their aesthetic, cultural, religious, or functional aspects. The official definition of craft includes two basic aspects—the predominance of human skill and labor involved in the making process and the substantial presence of artistic/ornamental work granting it a unique appeal. In accordance with this, the unique aspect of India's craft sector has been its continued reliance on traditional patterns,

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processes, and technologies [2], relying predominantly on skills that have been passed on generationally through largely family-based units. The drawback has been an inability to go in for potential technological upgradation, and subsequent improvement in process; especially, with respect to health and safety [3]. In a number of instances, Indian handicraft industry also continues to be hazardous in its practice. As a consequence, these craft pose serious occupational health and safety issues similar to those seen in manufacturing of mass produced goods, especially in context of material handling and forming.

At the same time, globally and in India, craft have showcased human being's supreme skill and artistic capabilities. Many craft have reached a level of refinement over centuries of practice which may even compete with machine led accuracy levels. Also, within craft, when passed from the master to the learner, a set of protocols (SOPs) are also handed over, so that strict procedures of maintenance, quality, and excellence continue to be practiced and retained by the next generations. However, some of the craft, esp. high-temperature-based metal craft do pose serious health hazards and workplace safety issues similar to what is seen in industrial setup.

37.2 Overview of Metal Craft

37.2.1 Metal Craft in India and Odisha

India has traditionally been a producer of metal-based handicraft since eleventh century and before [4, 5]. Art metalware forms a significant component of India's handicraft-based exports, with estimated Rs. 4705.64 crores attributed to this sector in 2016–17 out of Rs. 24,392.39 crores exports of handicraft (other than hand knotted carpets) in the same period [6]. A number of geographical clusters have evolved around metal handicraft work in India [7]. Across India, under different names, bell metal, bronze, and brass-based handicraft are popular since time of ancient, medieval, and modern history. Utensils, bells, decorative pieces, musical instruments, and statues as metal craft have been part of Indian history as a glorious expertise.

In the area of craft, Odisha, an eastern Indian state has a rich tradition, with a number of craft actively prevalent. Among these are the craft-based clusters of Pipli with its appliqué work, tie and dye textile-based work in Sambalpur, silver filigree work of Cuttack, dhokra or lost wax based metal casting, and bamboo and paddy root and straw-based figurines [8]. Delicate articraft and functional religious utility have been the raison d'être for the emergence of metal-based handicraft products. Prominent within the state are the bell metal products, or "Kansa", made from a variation of bronze with 4:1 ratio of copper to tin and brass metal made from an alloy of copper and zinc. Geographical clusters have emerged where artisan families settled, including the districts of Cuttack, Dhenkanal, Jajpur, Nayagarh, Khorda, and Sambalpur [9].

37.2.2 Balakati Bell Metal Cluster, Bhubaneswar

The selected cluster of art metalware for this study is the Balakati area of Khorda. The cluster primarily consists of family-managed units that make domestic utensils and decorative ritual wares made of brass and bell metal. Bhubaneswar, Cuttack, nearby towns, and the neighbor state of West Bengal are the primary markets for the cluster. Most of the raw materials used by the craftsmen are available courtesy old utensils that have been sold in the recycled market which are further melted and shaped into desired products through the process detailed below. Repair of old utensils and reselling them is also done where possible. The craftsmen have tie ups with local market shops specializing in brass and other utensil ware and produce items based on direct orders. Certain degree of soft support has been provided to the cluster through government departments such as MSME Cuttack, Directorate of Handicrafts and Cottage Industries, and ORMAS, a rural marketing body (Table 37.1 and Fig. 37.1).

Product range of the Balakati cluster includes utensil items such as below:

Table 37.1 Snapshot of Balakati metal craft cluster [10]

S. no	Key points	Description
1	Products manufactured in the cluster	Domestic utensils ritual wares and utility items
2	Name of the cluster	Balakati Kansa Pital Hastashilpa Unnayana Sangha
3	No. of functional units in the clusters	103
4	Turnover of clusters	Rs 25 crores
5	Employment in cluster	1000
6	Average investment in plant & machinery	Rs 50,000 to Rs 5,00,000
7	Testing needs	For quality of raw materials
8	Major issues	Diversification of products; Skill upgradation, marketing & export
9	Major markets	Domestic, nil exports

Fig. 37.1 Thali—plate; Thalia—quarter plate; Bati—bowl; Tatia/Gina—cup. *Source* photographs taken from Balakati cluster during walk-through survey

37.2.3 Metal Craft in India and Odisha

Bell metal is an alloy of tin and copper. Mostly, it is used to make bells and other similar products. Though bronze is a similar alloy of copper and has 12% tin, bell metal has higher percentage of tin. Both bell metal and bronze may have other metals like zinc, manganese, aluminum, silicon, and arsenic. In contrast, brass is an alloy of copper and zinc, and thus has different properties as seen in Table 37.2 below. Bell metal has higher tin content than bronze and brass is known for its wear and tear resistance, is non-ferromagnetic, and has acoustic depth and antimicrobial properties. The process of metalware making is carried out through two basic routes: casting in molds and through constant beating (pita) in order to achieve the desired shape and size. Metal casting is a process followed in more delicate, ornamental work including statues, forms etc. However, no bronze or bell metal casting is done in Odisha currently though dhokra casting (lost wax—Dhokra or cire perdue method) is done mainly by a specific tribe called sithulias [11]. On the other hand, forging and beating are common in utensils and ritual ware which may be decorated via engraving [12] (Fig. 37.2).

Table 37.2 Walk-through survey result

Process	MAT	PERSON	Reaction	Waste	CONTR	ROE	PPE
Melting	CU,SN,ZN,C	2	LIQ/VAP	C,FUM,	NO	INH	NO
Dieing	CU,SN,ZN,C	4	LIQ/VAP	SC	NO	INH	NO
Reheating	CU,SN,ZN,C	2	SOLID	C,FUM,	NO	INH	NO
Beating	CU,SN,ZN,C	8	SOLID	SC	NO	ING	NO
Quenching	CU,SN,ZN,	2	SOL/	C,FUM	NO	INH	NO
Scrapping	H20	2	VAP	FUM,DUS	NO	INGH	NO
Engraving	CU,SN,ZN	1	SOLID	FUM	NO	INGH	NO
Buffing	CU,SN,ZN	2	SOLID	DUS,FUM	NO	INGH	NO
	CU,SN,ZN		SOLID	DUS			
				DUS			

INH—inhalation, ING—ingestion, INGH—both, FUM—metal fumes, DUS—dust, and C—carbon

Fig. 37.2 Process flow—brass and bell metal crafts

37.2.4 MetalWare Through Beating (Pita)

The process followed in metalware making in the cluster has been detailed below

The area where metalware work is carried out is called as a sala or shed. There are two stages of melting followed—in the first stage, scrap or old metalware/ore is melted in an open furnace and poured into small molds or containers, called as billets. In the second stage, the metal is reheated and then forged by harmonious beating and hammering to give it the desired shape. Further processes include scraping, buffing, polishing, and engraving largely done using hand tools or simple lathe (Fig. 37.3).

37.2.5 Metal Hazards

Pre-industrial and industrial times have always been linked with occupational health hazards related to metal forming processes. Common metal-based processes of health concern are extraction, smelting, founding, machining, hot metal work, welding, and thermal cutting. Metals are generally found in solid state and therefore, inhalation in form of aerosols, such as dust fumes or mist has been detailed. Significant amount of metals also enter the body through ingestion. In some cases, metal is also inhaled as a vapor. Metals can also penetrate through skin cuts and abrasions. Melting a metal for processing is an integral part of metalware production regardless of the specific method used. For this purpose, various types of furnaces may be used, including coke-based, such as in the selected case. As per Taft, solid fuel, i.e., coal-/coke-based furnaces result in high levels of suspended particulate materials (SPM), and toxic gases such as SOx and NOx [13]. Usual level of emission of SPM and SOx during metal heating process in such foundries was estimated at approximately 1000–3000 mg/NM^3 and above 700 mg/NM^3, respectively. These levels are much higher than the norms by Central Pollution Control

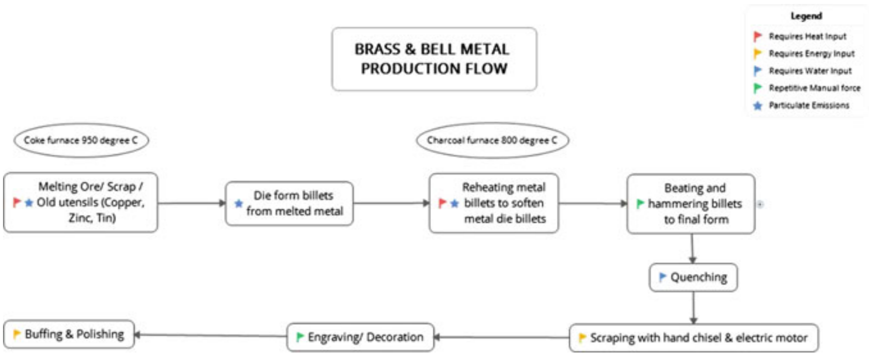

Fig. 37.3 Process map brass/bell metal craft: inputs (heat, energy, water, and force) & emissions

Board for above parameters, i.e., (i) suspended particulate material (SPM) at 100–150 mg/NM^3 and (ii) 350 mg/NM^3 for So_2. The human body operates best in moderate climate with core body temperature of 36.8 °C. Craftsmen in heated environment can be subjected to severe heat stress. Body's physiological response to the stress is shown through sweating, increased heart rate, and elevated core temperature, also called as heat strain. This may result into behavioral disorders, heat rash, heat cramps, fainting, heat exhaustion, and heat stroke [14]. Working with metal requires foundry work involving high temperature, resulting in repetitive burn injuries of hand and feet [15]. Since metal craft involves working with human hands, the process is very hazardous and physically demanding. The problems with the metal craft sector include lack of extensive value chain, raw material availability (most rework with old items), higher vulnerability of craftsmen due to poor socioeconomic status, and absence of process sustainability. Toxic nature of metal and its oxides have been very well established. Major toxic metals have been named as mercury, lead, cadmium, chromium, zinc, and nickel. Minor health hazards have been correlated with metals such as Aluminum, copper, and manganese. Copper fumes are produced at very high temperature and is not common. NOHSC puts copper fumes and copper dust limits to be 0.2 and 1 mg/m^3 respectively. In poorly ventilated places, craftsmen may be affected by zinc fume fever. Major route of entry is inhalation while it may also occur through ingestion. Zinc has high solubility and is readily absorbed, resulting into zinc chills where it enters the lung space. A number of researchers have studied hazards emanating from working with metals. For instance, [16] detailed the phenomenon of metal fumes in foundries where melting process of various metals was carried out. Among the hazards described, the researchers specifically discuss zinc fume fever, also called as "Brass founder's ague." This fever-related conditions were found even in foundries with zinc fume concentrations as low as 5 mg/m^3. The researchers also attributed gastric complaints by foundry operators to increased zinc concentration among them. Further, exposure to metallic copper dust in concentrations of 0.1 mg/m^3 was also suggested as responsible for a condition similar to metal fume fever among workers.

Nemery [17] studied exposure to various types of metals and the correlation with pulmonary functions and acute as well as chronic respiratory disorders. In India, a comparative spirometric study was carried out to understand long-term impact of exposure to metal dust in brass and steelware industries in Moradabad [18]. Through the study, researchers showed statistically significant differences in presence of one or more respiratory symptoms among metal polishers in comparison to a control sample. The study also suggested that long-term exposure to multimetals (>10 years) led to a statistically significant acute reduction ($P < 0.001$) in all pulmonary functions, hence indicating adverse respiratory effects among polishers [18]. Further analysis and implications of metal fume fever suggested it to be a benign, self-limited syndrome caused by inhalation or exposure to both metal oxide fumes and dust [19]. Typical symptoms include fever, muscle pain, headache, nausea, profuse sweating, and rigorous shakes, though these may get resolved within 1–3 h, or, in severe cases, within 1–2 days. A study on occupational hazards of brass foundry workers in Sri Lanka substantiated majority of these symptoms, while also finding the brass foundry operators were found to have higher zinc levels in red blood cells. The study also suggested that a number of workers failed to develop tolerance to metal fume fever phenomenon even after having worked for more than 5 years [20]. This has implication for preventive work conditions and avoiding extensive exposure.

Yet another area of occupational hazards in context of craft-related work is comprised of ergonomic/musculoskeletal disorders. Craft related work is dependent upon hand-based tools requiring either repetitive action, or use of excessive external force and therefore, is deeply interlinked with various musculoskeletal disorders (MSDs). In India, research in context of ergonomics and handicraft have analyzed such issues among workers related to multiple areas of craft such as hand block textile printing industries in Jaipur, Rajasthan [21], female craftspersons in West Bengal [22], (see also [23] for a review of occupational health and ergonomics across small-scale industries in India). A study of 120 goldsmiths in Davangere, Karnataka found a high degree of repetitive activities in their daily work, with consequential high frequency of MSDs including neck and lower back pain, as also eye problems on account of the high precision work involved [24]. Ganguly et al. [25] interviewed brass and bell metal craftsmen in Bankura district, West Bengal, wherein musculoskeletal pain was reported as the primary health concern, including back, knee, and joint pain.

37.3 Methodology

The present study is based on primary data from an interview sample of 37 bell metal workers in Balakati area of Khorda, Odisha. Respondent selection was done through convenience sampling. Process mapping was done through walkthrough survey, role analysis, and video recording of the various stages of brass and bell metal production process. Walk-through survey is routinely taken up by health and safety evaluators to look at processes and materials. The details include process, material used/handled, number of workers, reactions and wastes, controls in other critical issues informed by craftsmen included stomach upset, and extreme body pain. Two elderly craftsmen complained of early aging, and breathing problems, and one of them also suffered a paralytic attack. Many craftsmen complained of general tiredness, and signs of physical injuries. All the above parameters were at critical level of operation—place, housekeeping, visual examinations for dusts and mists, routes of entry, and personal protective equipment (PPE) available and used [14]. This framework was used to document the process. Traditional process mapping technique and craftsmen interviews was also done.

37.4 Results and Discussion

The process mapping and walk-through survey very clearly established the presence of following hazards: zinc and copper dust, coke fumes, CO_2, CO, fire flakes, and heat stress. These hazards have also been well established through literature survey and existing studies. The craftsmen complained of suffering through repeated fevers (jara) which may be, if medically proven, be related to zinc chills or metal fume fever. The craftsmen also complained of profuse/extreme sweating. Other critical issues informed by craftsmen included stomach upset, extreme body pain. Two elderly craftsmen complained of early aging, and breathing problems, and one of them also suffered a paralytic attack. Many craftsmen complained of general tiredness, and signs of physical injuries. All the above parameters were at critical level of operation.

The process of metal craft comprises of 7–8 craftsmen squatting in a circle and rhythmically beating a small heated part at the center with high frequency and severe force. This act becomes extremely hazardous and has resulted into severe injuries from time to time. The hand-held equipment used for beating are sharp, heavy, and some of them greater than 2 kg which gives substantial scale of injuries to the craftsmen—bare-bodied while working. Exposure to hazards under such conditions is very high. RUBA/RELA assessment through posture analysis involved in rhythmic beating process was also carried out. The assessment also reveals a high-category score necessitating immediate intervention in the work process. Most of the postures put forth the danger and hazards of repetitive stress injuries and locational severe body injury (such as tennis elbow and knee issues). Though the craftsmen operate harmoniously following a rhythmic pattern showing exemplary teamwork, coherence and expertise, the act would fall under highest severity as far as workplace hazards are concerned. Though this paper has not medically correlated the findings, following could be established with the help of questionnaire survey and visual examination (Fig. 37.4).

There was complete absence of any form of use of personal protective equipment in form of masks, gloves, and goggles. In fact, most of the craftsmen were

Fig. 37.4 Observational analysis of repetitive stress injury study. Standards source from [26]

completely bare-bodied during the work process. The situation may be further exacerbated in summer months, when the ambient temperature during daytime is consistently high. The emphasis in the current study was on identification of various types of hazards faced and risk exposure potentialities in the entire production process. While some hazards faced such as high solid particulate matter and fumes from burning coke/charcoal and metal oxide and dust are well established, mapping the entire process allowed for comprehensive analysis of occupational hazards including metal toxicity, heat stress, and observational assessment of musculoskeletal disorders. Further technical and epidemiological studies suggested for detailed assessment include repetitive posture analysis, noise analysis, incidence recall, and pollution-based studies (Fig. 37.5).

Use of solid fuels for melting and softening of metals is highly inefficient in terms of energy consumption while also being a serious health hazard for the workers. Pilot projects for shifting from traditional solid fuels such as coke and charcoal to modern bioenergy methods such as using rice straw or biogas-based gasifiers have been attempted elsewhere though doing so will require pooling together of a number of smaller units and therefore require a change in the production process. Additionally, few studies have carried out comprehensive monitoring of metal hazards with regular sampling of metal dusts, fumes, and indoor ventilation analysis. Tight process control, adequate localized ventilation, and engineering controls are recommended. Though it may not be life threatening, respiratory protective equipment with proper filter must be consistently used. Further, putting controls in place for workplaces with metal hazards is contingent upon the type of metal and its state. Appropriate respiratory protective equipment and general handling practices need to be strictly put in place in above scenario wherein high-temperature handling of metals leads to exposure, injuries, and

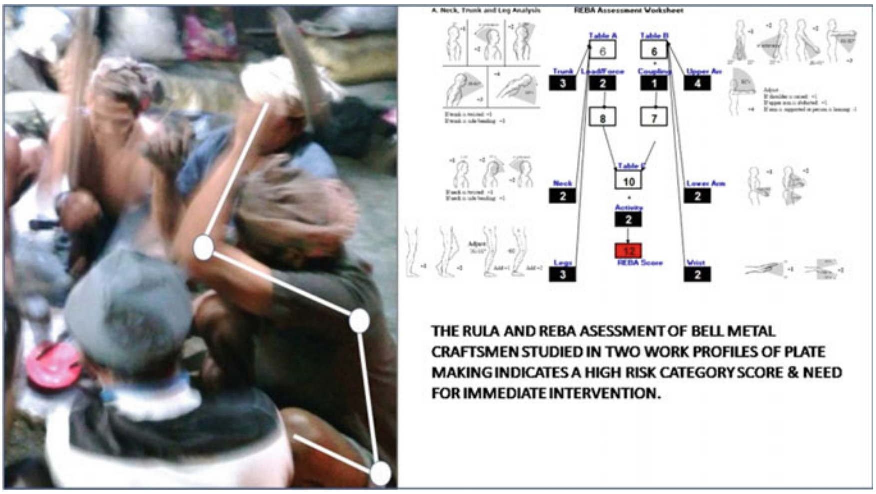

Fig. 37.5 RUBA/RELA assessment of work process involved in bell metal craft

long-term MSDs. Ergonomic analysis of worker posture, including upper limb repetitive motion studies and overall posture and force analysis were found useful as the first step for designing safer, efficient, and comfortable workstations. In high risk severity processes such as the sample, industrial scale safety analysis and due engineering control practices and equipments need to be put in place.

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Chapter 38
Ergonomic Postural and Biomechanical Analysis of Manual Weeding Operation in Agriculture Using Digital Human Models

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Abstract The agricultural land of India is approximately 181.95 million ha (55.3% of entire area) where the majority of the landholding (i.e. 78.92%) are in the category of a small and marginal group. Weed control is one of the most challenging and labour-intensive operations in agriculture utilizing about 20% of human energy and 25% of labour requirement. Further weeds alone reduce about 50–70% in crop yields. Manual weeding operation is most widely used by small and marginal landholding. Manual operation is associated with different types of health hazards, such as musculoskeletal disorders (MSD), pain in various body parts, injury, etc., among farmworker due to ignorance of the capabilities and limitations (anthropometric and biomechanical characteristics) of the potential user group in the design of tools and equipment. Moreover, practising manual and wheel hoe weeding required more human energy, i.e. vary from 300 to 400 man-h/ha and 50 to 125 man-h/ha, respectively. The present study attempted to evaluate existing manual weeding using wheel hoe in the digital environment, using digital human modelling (DHM) for the prevention of work-related musculoskeletal disorders. The DHM has become commonly used for human-centred product design. The DHM tools have the potential to analyse and improve the product before it's ever launched. Therefore, the emphasis in this paper is to investigate the postural and biomechanical behaviour in manual weeding practices for the various user group (i.e. 5th–95th percentiles) of Arunachal Pradesh. The outcome of the postural analysis found to be more discomfort rating for the larger group of population (i.e. 50th–95th percentiles) for male workers in wheel hoe operation. Further, the compressive forces on L4–L5 lumbar spines showed higher values for wheel hoe for both male and female. A similar type of approach using DHM for others existing agricultural tools and equipment would improve human comfort, safety and overall productivity.

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38.1 Introduction

In India, the land shared by the small and marginal farmer is about 78.92% [1] whereas the north-eastern (NE) region mostly belongs to this category. The proportion of net sown area to the total area is as low as 15% against 46.6% for all-India average [2]. Agriculture is a backbone and vital sector in the economy of the NE region, with its share in State Domestic Product (SDP) ranging from 19 to 37% in different states [3]. Weeds can be considered a significant problem in this region because they tend to decrease crop yields by increasing competition for water, sunlight and nutrients while serving for host plants to control pests and diseases. The weeding by hand or hand tools such as hand hoe and weeding hook are widely used in rural India. Weeding is a time-consuming and labour-intensive operation taking about 15–20% of the total man-h involved in crop production. The energy demand of weeding operation with the hand tool in bent and squat posture is 9.3–14.4 kJ/min with work severity of light to heavy [4] and energy demand of wheel hoe weeder is 13.6–28.2 kJ/min [5]. The available weeding period is limited due to the high soil moisture in the field which demanded some other efficient weeding methods such as mechanical, chemical and biological weeding [5]. In the dry land, the workers remove weeds by sitting on the ground with one or two legs flexed at the knee, whereas in the wetland, the workers opted stoop posture for weeding. Each way of doing the weeding tasks exerts postural stress. Frequent use of such tools for longer duration leads to discomfort during work which reduces the efficiency and job satisfaction of workers. Improperly designed manual tools and improper work practices put the workers at risk causes various health issues such as musculoskeletal disorders (MSD), low-back pain, and injury. Since the weeder designs by local practices without considering standardization, therefore, lots of variations found in technical specifications [6, 7]. The problem associated with manual weeding like stress and discomfort in human body parts can access using virtual simulation. Unwillingly, the workers adopted awkward posture due to the characteristics of the workplace and work pressure to finish the task within the stipulated time frame. Inadequate working posture can constitute a risk factor. Digital human modelling and simulation (DHMS) refers to the digital representation of human inserted into a simulation or virtual environment to facilitate prediction of safety and/or performance [8]. Appropriate ergonomic design is imperative to prevent monotonous strain injuries and other work-related musculoskeletal disorders (WMSDs), which can develop over time and lead to long-term disability [9].

Although various mechanical weeders are technologically advanced in India however, limited designs are suitable to NE region. The most of the agricultural farmers are not able to purchase weeders against their requirement for various crops. Therefore, it is utmost essential to design user-friendly to improve operational comfort and reduce weeding cost.

38.2 Methodology

This research focused on the virtual ergonomic evaluation of manual weeder considering the anthropometric database of Arunachal Pradesh farmers of the 5th–95th percentile population. The virtual simulation provides key benefits like shorter design time, reduced redundant changes, lower manufacturing costs, better quality, increased output and enhanced safety leading to heightened morale.

38.2.1 Generation of Digital Human Models and Rendering of Comfort Posture

State-of-the-art digital human modelling has been widely and commonly used within the product development process since its early stage up to the production and delivering [10]. For evaluating human–machine interaction considering anthropometric diversity by creating human models, so-called mannequins of different sizes and proportions are essential. In the present study, anthropometric data of Arunachal Pradesh [11, 12] have considered for ergonomic design and evaluation of CAD model for wheel hoe. The digital human mannequins were built to accommodate the target range of farmworker using the anthropometric database in the DHM simulation system. The various percentiles of digital human models (5th, 50th and 95th percentiles) for both male and female were created to represent a small, average and large dimension of the population, respectively (Fig. 38.1).

The push/pull wheel hoe design suitable for NE region of India has not yet established because of variation in anthropometry database. The ergonomic evaluation of the manual weeding practices was carried out in two steps. Firstly, all the

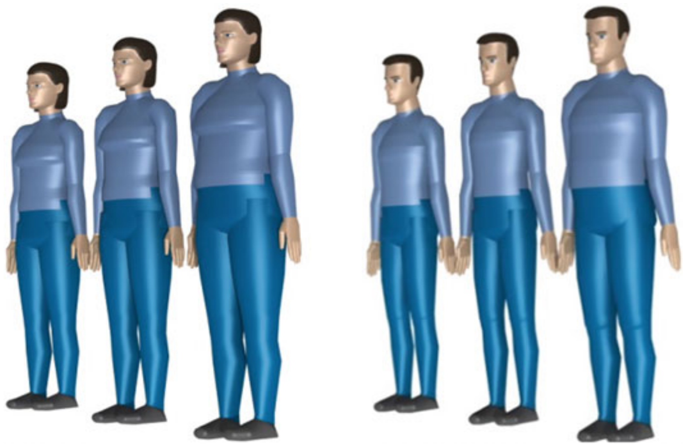

Fig. 38.1 5th, 50th and 95th percentile male and female custom-built digital mannequins

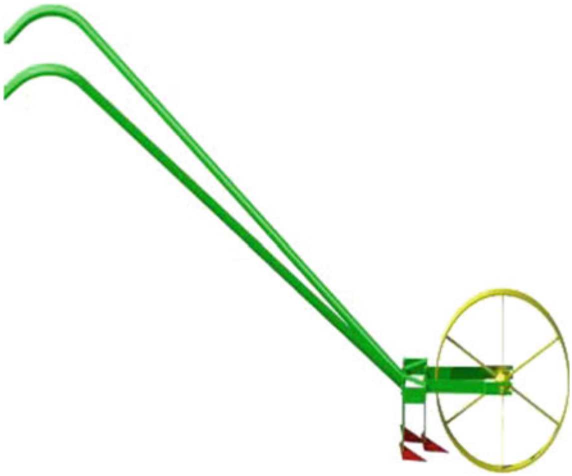

Fig. 38.2 3D model of wheel hoe

functional and structural dimensions of available wheel hoe were taken and converted into the 3D model (Fig. 38.2) in CATIA software and then simulated with the digital mannequin of farm worker of Arunachal Pradesh (Figs. 38.5 and 38.6) in DELMIA (V5R19) digital human modelling software for ergonomic postural and biomechanical analysis. The main dimensions of push/pull weeder are wheel diameter = 33 cm; handle length = 111 cm; handle height = 100 cm; handle grip spacing = 42 cm; weeder blade length = 8.2 and breadth = 7.2 cm; blade height = 12 cm; blade supporting frame = 20 × 5.5 cm; and number of blades = 3.

38.2.2 Interfacing Digital Human Models with the Manual Push/Pull Type Wheel Hoe

Various steps considered for the study like workplace surveillance, virtual simulation and risk assessment. In the workplace, operational activity, physical dimensions of weeder, photographs of weeding (Figs. 38.3 and 38.4), working posture and working environment have studied and portrayed into a frame of virtual simulation (Figs. 38.5 and 38.6). During the manual weeding operation, the operator has to walk behind the wheel hoe by holding the handle nearly at the waist height. The worker has to bend in the forward direction for weeding with wheel hoe to maintain the stable working posture.

From the field observation, it was noted that the shorter operator has to perform with the slide forward leaning, but taller worker person, more bending is required for proper handle gripping and efficient weeding operation.

Due to continuous operation, the worker feels various stresses in various body parts. Agricultural activities of a repetitive nature executed by both males and

Fig. 38.3 Weeding activity —pushing position

Fig. 38.4 Weeding activity —pulling position

females should design in such ways that the force requirement does not exceed 30% of the 5th percentile value of maximum strength capability of female workers. Therefore, the recommended grip strength for male and female agricultural workers of NE should be 5th percentile of female data which was 10.90 and 6.52 kg for dominant and the opposite hand, respectively [13]. Therefore, maximum force required to pull/push the wheel hoe has considered 3.6 kg for postural analysis.

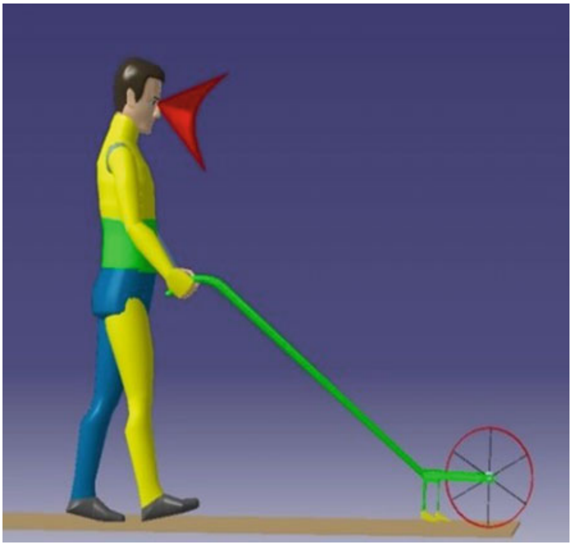

Fig. 38.5 Man–machine interaction while pushing in CATIA

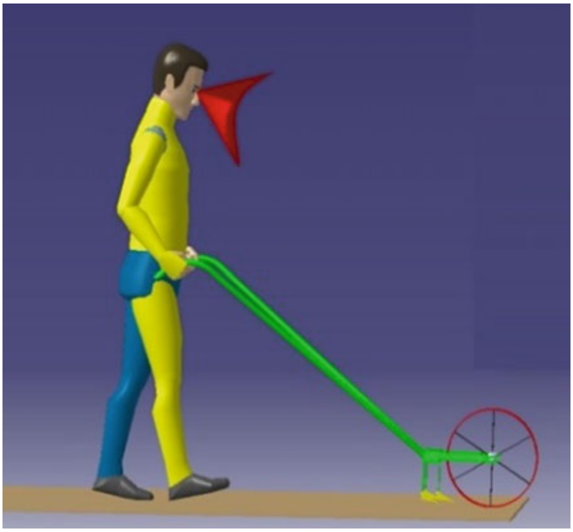

Fig. 38.6 Man–machine interaction during pulling in CATIA

38.2.3 Posture Analysis

Subjective observation method (i.e. RULA method) for postural analysis focused on the upper part of the body. It ponders on the particular attention of the upper limbs, neck, and trunk and several WMSDs [14–17]. The final score varied between 1 and 7 as shown in Fig. 38.7 based on the estimated risk due to musculoskeletal loading and also expressed using colour coding [18].

RULA score	Colour coding	Action required/Inference
1		Acceptable
2		Acceptable
3		Investigation further
4		Investigation further
5		Investigate and change soon
6		Investigate and change soon
7		Investigation and change immediately

Fig. 38.7 Colour coding for classification of risks according to postural scores

38.2.4 Biomechanical Analysis

Mechanical load on the lumbar spine considered as a contributing factor to many of the lower back anomalies [19]. The compressive forces on L4–L5 lumbar spines, due to the mass of a body plus load acting on hand and trunk, have a safe/cut-off limit of 3433 N with the maximum permissible limit of 6376 N, as recommended by the National Institute of Occupational Health (NIOSH) [20]. This methodology was adopted for observation of maximum compression force generated in the lumber segment during pulling and pushing weeding operation with the same posture that most workers followed for 3.6 kg load.

38.3 Results

38.3.1 RULA—Working Posture Assessment

The RULA and postural score analyses were performed by considering 5th, 50th and 95th percentile anthropometric database. In this analysis, weeding operations were observed and captured in image and video format. Further, it was analysed for pulling/pushing operation along with posture. The most commonly adopted working postures were simulated in virtually with CAD model of wheel hoe and further RULA and biomechanical analysis was carried out. Keeping operator right foot as a reference point and the intermittent operation was considered as a mode of operation for RULA and compression force analysis.

The RULA score of 3 for pulling and pushing operation of the 5th percentile male worker was found insignificant which shows acceptable limits but suggested for further investigation. The body part score like wrist and arm was found a higher score, i.e. 3 for pull and 4 for push compared to other body parts. Trunk score was found ≤ 2 in both the cases. Similar results obtained for 5th percentile female worker in both pull and push operations except wrist score of 3.

For 50th percentile male workers, during pushing operation, the upper body parts such as upper arms, forearm, wrists, wrist and arm and trunk showed the higher score. However, the final score was 5 which suggested the further necessary investigation and changed the working posture with suitable design modification as shown in Fig. 38.8.

However, for pulling, only wrist and arm has the higher score which may be due to more stress generated in the hand portion indicating final RULA score of 3 which was less than pushing. For the female worker, slightly lower score (i.e. 3) was obtained which signifies the suitability of posture and design for both pulling and pushing operation of weeder as compared to the male worker but further investigation was recommended for more comfort of operation.

For 95th percentile worker (Fig. 38.9), higher RULA score was found for pushing operation (i.e. 5) than pulling operation (i.e. 4), but both operations indicate further investigation and change the posture and design soon. Trunk score was found higher value (i.e. 3) which may be due to more forward bending of the worker. Higher trunk score is most sensitive to the worker, and for safe operation, it should be lower [28]. Within the same population group, i.e. 95th percentile female worker of this region, have shown final RULA score of 4 implies the further investigation and suggested not acceptable current design and working posture. From RULA analysis, it was found higher score in pushing of wheel hoe as compared to pulling operation as shown in Table 38.1. Among the RULA results for all selected percentiles of the user group, only 50th and 95th percentiles of a male are shown in Figs. 38.8 and 38.9.

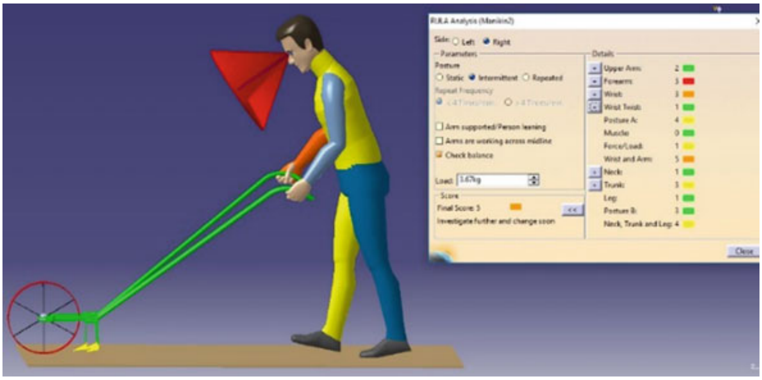

Fig. 38.8 RULA score of 50th percentile male worker during pushing operation

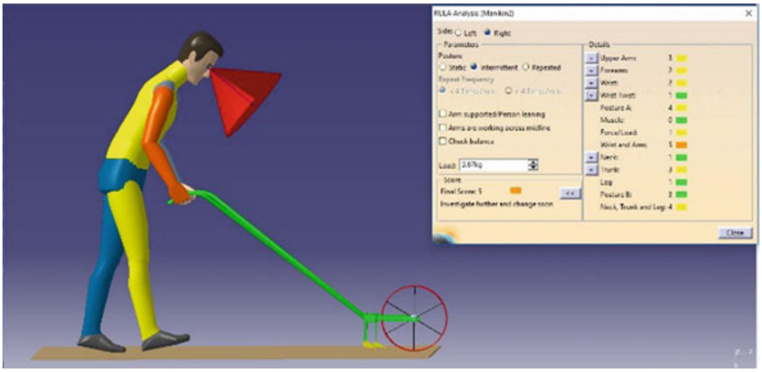

Fig. 38.9 RULA score of 95th percentile male worker during pushing operation

Table 38.1 RULA score and BMCF for male and female worker

User group	Male				Female			
	Push		Pull		Push		Pull	
	RULA	BMCF	RULA	BMCF	RULA	BMCF	RULA	BMCF
5th	3	1229	3	1220	3	985	3	982
50th	4	1540	3	1533	3	1118	3	1119
95th	5	1742	4	1741	4	1237	4	1234

38.3.2 Biomechanical Analysis

The biomechanical analysis was carried out for single acting force analysis of L4–L5 spinal segment for all three-percentile user groups of both genders for a load of 3.6 kg at the intermittent stage and compared with the NIOSH limit. Biomechanical compression force (BMCF) evaluated for existing push/pull manual weeder. For the pulling, L4–L5 compression force of 5th, 50th and 95th percentile male was 1220, 1533 and 1741 N and for pushing 1229 N, 1500 N and 1742, respectively. For the female operator, forces were 982, 1119 and 1234 N in the case of pulling and for pushing 985, 1118 and 1237 N, respectively (as shown in Table 38.1). The absolute values of the L4–L5 compressions were found to be within acceptable limits. The results showed that all the compression force at the lumber section were below the safe limit [20]. For the representative sample, the result of 95th percentile of both male and female were shown in Figs. 38.10 and 38.11, respectively.

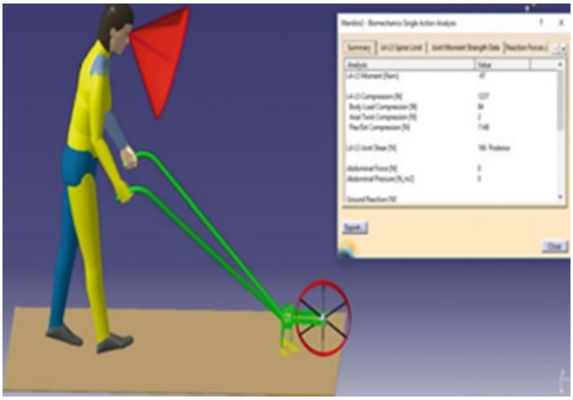

Fig. 38.10 Biomechanical compression force of 95th percentile female worker

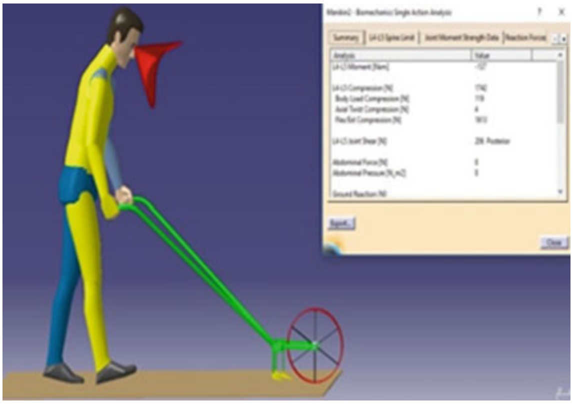

Fig. 38.11 Biomechanical compression force of 95th percentile male worker

38.4 Discussion and Conclusion

While designing various agricultural hand tools and equipment for NE region, little attention has given to the users' competencies and limitations [21, 22]. CAD and DHM technologies have made it possible to identify key design issues behind difficulties which may be encountered by workers in performing their tasks in the early phase of the design process and can reduce the risk of human–machine incompatibility problems [23]. The core functionality of DHM software is a realistic display of anthropometric data and the effective analysis of ergonomic issues concerning sight, maximum force, reachability and comfort [24–26]. Designers can subsequently utilize a human model in the creation, modification, presentation and analysis [27] to ensure enough clearance and space to a person for their ease and comfortable movement within the workplace. NE worker is smaller compared to other region of India, and there is a slight variation of some parameters among NE states. It suggests that tools and equipment designed for covering a wider percentage of the user group [28]. The use of colour coding techniques confirms that problem areas for quickly identified and iterated to optimize better working posture [28]. The identification of the possible areas of improvement at a new workstation to minimizes awkward stances and risk of WMSD among the workers [29]. The anthropometric body dimensions of the operators associated with the height of the workstation influenced the maximum comfort level of lumbar muscle and the comfort level of working posture when workers are performing their jobs [28]. The present study found that the 50th and 95th percentiles of male worker show higher RULA score of 4 and 5, respectively, which was similar to the results obtained by Khayer et al. [28] for a pedal operated paddy thresher. Suitable application of ergonomics in work envelope design helps to obtain acceptable work efficiency. The motive of this modification and adjustments is to analyse various postures adopted by different manual operating farm tools and equipments. The push/pull type weeder was evaluated in a virtual environment with digital human modelling software for its feasibility to implement in a real scenario. The present research article motivates the readers to access the massive scope of DHM technology for ergonomics analysis and evaluation of various tools and equipment to improve comfort and productivity.

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Chapter 39
Modular Assistive Devices for Elderly People to Overcome Age-Related Problems

Swati Sarkar and Amarendra Kumar Das

Abstract India has witnessed the rate of growth in the elderly over the past few years, and studies show that the elderly people are more prone to the various factors causing disability. Physical and sensory impairments are common issues with their advancing age. Due to inability in performing the daily activities, a major portion of the elderly population is dependent on family members or caregivers. Various studies show the tremendous enhancement in the physical and cognitive ability in the elderly with regularity in resistance and other exercise training. Although various facilities are already availed by many elderly people, these facilities are not fully extended to many other elderly from remote or rural part of India. Most of the designs attribute to the younger generation of the society providing fewer avenues to the elderly. Therefore, designing such equipment which can also be afforded by the rural elderly people is of utmost necessity.

39.1 Introduction

An elderly is defined as a person who is of age 60 years or above, according to Government of India's 'National Policy on Older Persons' [1, 2]. The disability in elderly people can be categorized into the following three groups: (i) who are able to manage their daily activities using the mechanical devices; (ii) who are having multiple health problems and require intensive levels of care due to their limitations in mental or physical functioning; and (iii) who are functionally disabled in one or two activities of daily livings or have mild cognitive impairment [4].

In 2011, around 53, 76,205 elderly individuals were disabled in India, which accounts for 5178 per 100,000 elderly populations, which is about 5.1% [1]. In a systematic review, it was reported that higher body mass index, lack of schooling,

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depression, visual impairment, poor self-perceived health, cognitive impairment, depression, arthritis, diabetes, slow gait, sedentary lifestyle, tiredness while performing daily activities and limited diversity in social relations are the various risk factors for functional disability in the elderly people [1, 5]. There may be still many factors let that be environmental or individual that is yet to be identified and from the intervention point of view those are to be properly investigated.

Chandwani et.al reported in their study that 73% respondents felt that their day-to-day life is affected by their age and 58% reported that their daily activities are partially affected [3]. In the study (Venkatarao et.al.), it was found that functional limitation is prevalent in 88% of the geriatric population regardless of their gender [8, 12]. In Gupta et.al, out of 932 participants, for 836 participants the experiment was successfully carried out. Out of these 836 participants 172 (20.6%) had hypertension, 54 (6.5%) had diabetes, 193 (23.1%) had a history of joint pains, and 114 (13.6%) reported to have chronic obstructive pulmonary disease (COPD) [4]. Various interventions had been done to eradicate the menaces of the disability among the geriatric population.

The paper discusses the interventions done in the field of assistive technology for the geriatric population and elaborates the various mobility assistive devices. It also highlights the acceptance of the technology by the older community and the modularity and consideration needed in the existing technology in context with the older generation.

39.2 Review on Interventions in Disability in Elderly People

With the advancement in age, the physical and sensory impairment can be observed with varying degrees of disability [1]. It is an early trend of having cognitive impairments in older age, thereby, increasing the risk of falls, but it is strongly evident that, daily exercise may result in postural stability and prevent falls in elderly [10, 23]. In a study done by Reeves et.al (2003), eighteen participants (10 women and 8 men) underwent a strength-training programme using isotonic resistance exercise machines for 3 days per week for 14 weeks. They found enhancement of specific force by 19% after the programme [21].

Chiello et. al conducted a trial to determine the short- and long-term effects of the resistance training on psychological well-being, muscle strength, control beliefs and the memory and cognitive speed in normally active elderly people. The maximum dynamic strength significantly increased and the psychological well-being associated with the decrease in the self-attentiveness was enhanced in the training group [6].

In another study, Joshua et.al conducted individualized progressive resistant strength training (PRT) to see whether the PRT is more effective as compared to traditional balance exercise (TBE) or not. The effectiveness of the combination of both was also evaluated. In the experiment, three groups were made and in each group, eighteen subjects of age more than 65 years were included from the elderly care centres of Mangalore city in Southern India. The TBE group was indulged into eight component traditional balance exercises for 6 months (four times per week). The PRT group indulged into resistance training for the muscles of lower extremities. As a result, PRT intervention was found to be more effective than TBE among the non-frail elderly people [13].

Hariprasad et. al conducted a randomized clinical trial of yoga-based intervention on elderly from nine different elderly homes in and around Bangalore city, India, approved by the Institutional Ethical Committee of the National Institute of Mental health and Neurosciences. Eighty-seven elderly (yoga = 62 and the waitlist = 43) completed the trial for six months. For one month, the yoga group received the yoga sessions weekly until third month and after that continued for six months, henceforth, without any supervision. There was a significant improvement in the immediate and delayed recall of verbal and visual memory, attention and working memory [33].

There are many programmes run by the Central government with the help of the State government to support the persons with disability in India. The Ministry of Social Justice and Empowerment and Heath and Family Welfare in India have taken certain measures in curbing the menaces of disability-related problems in India [7, 32]. District Rehabilitation Centre (DRC) was started in 1985; National Information Centre on Disability and Rehabilitation and National Level Institutes like NIMH, NIHH and NIVH are initiated in India. District Disability Rehabilitation Centre was launched with the aim of providing rehabilitation services and implementation of Persons with Disability Act 1995 [7].

Community-based rehabilation services has also been promoted which includes advocacy, inclusion, participation, sustainability and empowerment. But, understanding the concept of disability and acceptance of the CBR and it as a valid intervention is still a challenge [7]. The Ministry has launched the 'Rashtriya Vayoshri Yojana' (RVY) which aims in providing physical aids and assistive living devices (crutches, walkers, hearing aids, artificial dentures, spectacles, etc.) to the senior citizens who belong to BPL category and suffering from age-related disabilities. This assistance can bring the normalcy in their bodily functions to some extent. A total of 187 districts from all states of India have been selected under this scheme [32].

39.3 Assistive Technology for Elderly People

In [15, 16], the assistive technology is defined as 'any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed'. In a study, Agree et.al, examined the assistive devices and the personal care as the factors while measuring the disability in a community of elderly people. They found out that although most of the elderly spends their life in good functional health, still two-thirds of their disabled years are spent with unmet ADL needs. These needs indicate the gap between the provision of the services and the level of need in a population as well [19].

Nagai et.al had developed a power-assisting device, mainly consisting of two parts in which the upper part was able to provide motion in horizontal plane while the lower provided the motion in vertical plane. It assisted the patient during the transition from sitting position to standing or walking position [11].

In India, there is a lack of awareness among the users and also among the concerned professionals, thereby making it as a constraint in the availability of the assistive and enabling technology in the country [34]. In a study (Kumar et. al), two groups have been identified for the assistive technology, those who: (i) require some support and assistance in their daily household activities but are not likely to be called as disabled and (ii) are older people with disabilities either inherently or acquired later in life. A total of 100 elderly participated in the survey. They concluded that the older generation is not apparently aware of the benefits of the AET and also the fact that how intensively it can improve their lives [34]. Tatsuo Ishibashi, a Japanese designer has focused on developing 3D printed assistive devices for elderly suffering from diminished physical functions, which enables the elderly people in accomplishing tasks like writing, typing and opening containers [36]. More researches are required to accomplish the development of 3D printed mobility assistive devices.

39.3.1 Mobility Assistive Devices

In elderly, the susceptibility to injuries caused by the diseases like osteoporosis or reduced protective reflexes, the danger of falls persists in elderly [22, 23]. Various mobility assistive devices are available to enable the elder population to carry out their daily activities with comfort.

(a) **Alternative Mobility Devices**
The alternative devices, wheelchairs and the special vehicles are considered optimal solution in case of total incapacity. Prolonged use of such devices can cause health issues like, loss of bone mass, degradation of blood circulation and physiological functions, osteoporosis and skin sores (Fig. 39.1).

(b) **Augmentative Mobility Devices**
The augmentative devices are used as external devices like crutches and canes or as the mobility training devices during a rehabilitation process or as self-ported devices as in orthoses and prostheses. These devices encapsulate the following devices (i) mobility training devices, (ii) self-ported devices and (iii) external devices. These devices enable the user to avoid the previously presented health problems and allow the patients to continue using their remaining locomotion capability. In some cases, the patient can regain their previous ability of locomotion and can relearn to walk safely and efficiently [23].

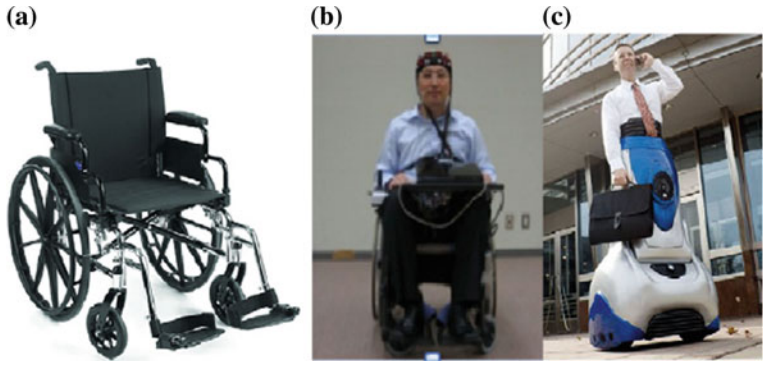

Fig. 39.1 **a** Manual wheelchair, **b** smart wheelchair and **c** bi-pedestation. *Source* Martins et. al

Mobility Training Devices—The intention of the use of mobility training device is to improve the gait and help in the movement of the patients during the rehabilitation process.

Parallel bars are considered as the most commonly used training devices [23, 24]. The parallel bar technique has found to yield good results during the rehabilitation process. In this kind of process, the involvement of two or three therapists is required, to assist the patient in walking and to hold their lower limbs to control their movement [23, 25]. Robotic mobility training devices also assist the patient in the rehabilitation process. According to the literature survey, it is evident that the patients should be intensively engaged in the training procedure else there is a tendency of losing interest with time [23, 26–28]. The robotic mobility training devices are further classified into three devices, (i) treadmill training devices, (ii) ambulatory training devices and (iii) feet manipulator devices. The treadmill training devices are the most commonly used training devices (Fig. 39.2).

The ambulatory devices are quiet similar to the treadmill training devices but it involves less equipment than the latter, and there is a provision of over ground training that and is considered as an effective training over a treadmill (Fig. 39.3).

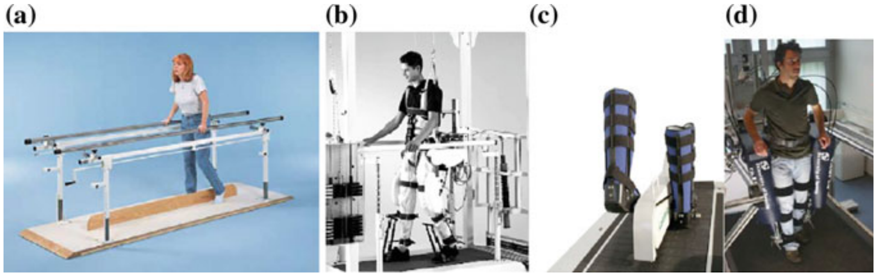

Fig. 39.2 **a** Parallel bars, robotic mobility training devices: **b** Lokomat, **c** LokoHelp and **d** Lopes. *Source* Martins et. al

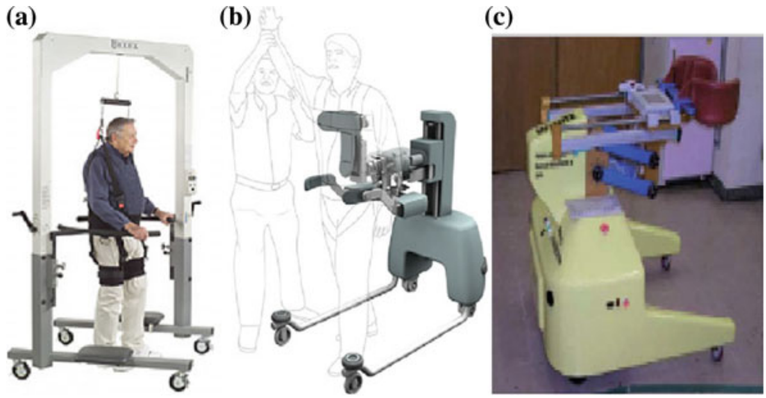

Fig. 39.3 Ambulatory training devices: **a** LiteGait, **b** KineAssist and **c** Where-I. *Source* Martins et. al

The feet manipulators are the training devices in which the patient's feet are held in the robotic manipulator where the manipulator supports and gently rehearses the patients with the continuous walking situations. The feet of the patients are kept on plates and the trajectories of the plates are fully programmed and can imitate everyday walking patterns like, walking, ascending or descending stairs and tripping or slipping. The artificial feet movements force the slack muscles between the toes and the hips to come into action again [23] (Fig. 39.4).

Self- Ported Devices—The self-ported devices are used either to substitute a lost limb (prostheses) or to improve the function of the existing movable parts of the body [23, 29]. These devices intend to restore mobility in the patients who have severe walking impairments (Fig. 39.5).

The orthoses are considered either active or passive. In active orthoses, the actuators or motors enable the movement by providing the energy. While in passive orthoses, there are no actuators or motors, instead the energy is provided by the users. The device is based on the gravity balancing principle (Fig. 39.6).

External Devices—Canes, walkers and crutches constitute the external devices. The canes are the most common among the all devices and are commonly used in increasing the gait stability rather than to partially supporting the weight [23, 30]. Crutches allow a direct support to the body and thereby providing a greater weight support in walking as compared to the canes. However, they are somewhat cumbersome and not favoured because they provide an unnatural gait (Fig. 39.7).

Walkers are very simple device but have a greater rehabilitation potential. These are mostly suggested in order to maintain balance and improve the patient's mobility. Various kinds of walkers are available in the markets based on the materials used in manufacturing, the accessories used, sizes, etc. Based on the classification, walkers are of two types, (i) conventional and (ii) smart walkers (Fig. 39.8).

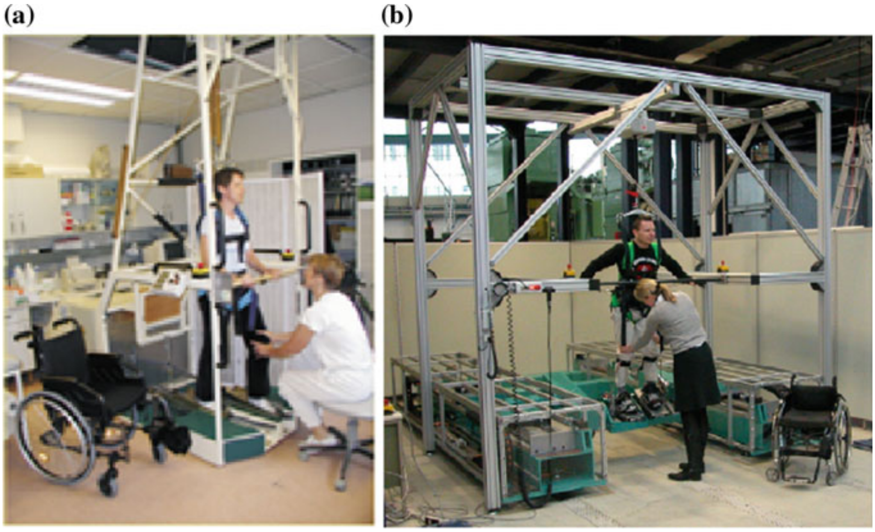

Fig. 39.4 **a** GaitTrainer and **b** Haptic Walker. *Source* Martins et. al

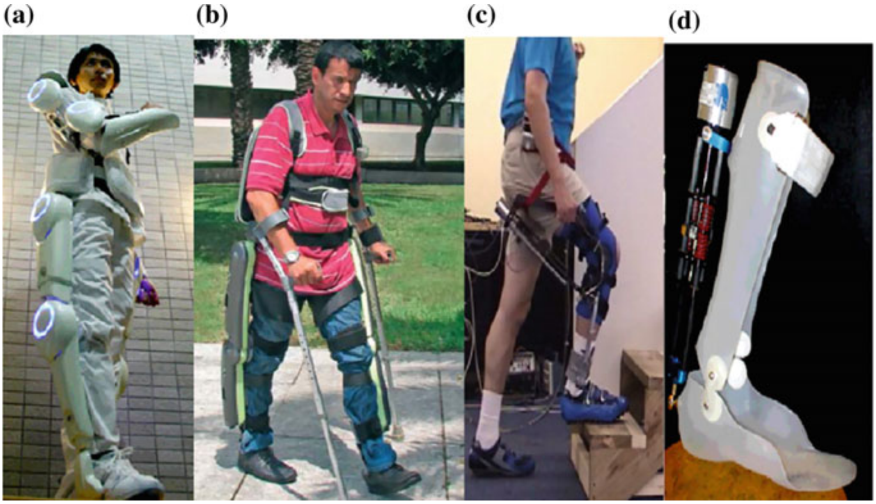

Fig. 39.5 Self-ported devices: orthoses **a** HAL-5 exoskeleton, **b** ReWalkTM, **c** RoboKnee and **d** MIT active ankle-foot orthoses. *Source* Martins et. al

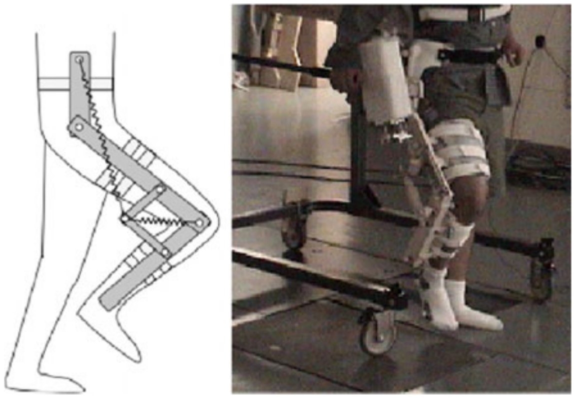

Fig. 39.6 Passive orthoses based on gravity-balancing principle. *Source* Martins et. al

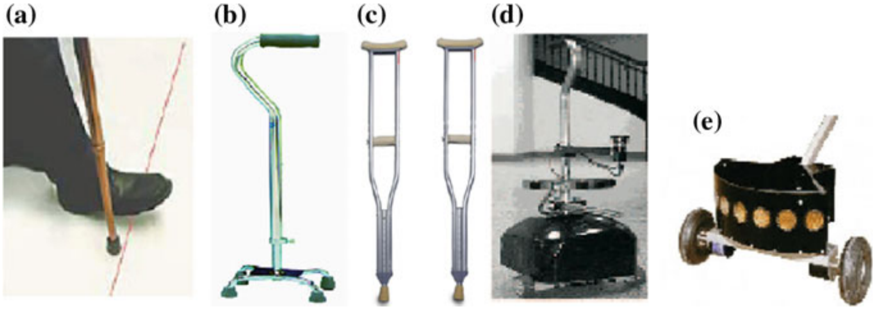

Fig. 39.7 External devices: **a** standard Canes, **b** multi-feet Cane, **c** crutches, **d** smart cane and **e** guide cane. *Source* Martins et. al

Fig. 39.8 Conventional Walkers: **a** standard walker, **b** front-wheeled walker and **c** rollator. *Source* Martins et. al

Although walker is easier than cane to use, there is a requirement of upper body strength and cognitive as well. If not used safely, it can result into an abnormal gait [23, 9]. And there is a chance that the patient may fall over backwards still holding the walker [23, 31]. Among the three types of walkers, rollators are the easiest to use, but considered less stable.

39.4 Need of Modular Assistive Devices by the Elderly People

Although older adults are less likely in using the technology than the younger adults, research shows that older adults are willing to use the technology when there is a need, but the benefits of the technology should be clear [14]. According to Resnik et. al, in a study, it was observed that due to social pressures and perceived stigma they deter use of mobility aids, particularly in the minority community [35]. In a study, sixty-seven people aging more than 69 years were interviewed about their experiences and usage of the wide range of assistive technologies. The most important characteristic of the assistive technology that is sought by the users is that it should work properly, reliably and safely [15]. The ease of use of a product determines its users. Various assistive devices are available worldwide but determination of its usability is of serious concern. In a study conducted with large number of samples (using the everyday common products), 75% of the participants reported difficulties in the usage [14]. The modularity in the assistive devices would enable the elderly in carrying out multiple tasks and thereby making the living conditions better. Wu et. al has developed the SmartCane assistive system which aims in reducing the risk of injuries from fall in elderly. This device provides the capability for local signal processing, remote sensing and real time feedback on the cane usage [17]. Schrock et. al designed the light wheelchair-mounted robotic arm (WMRA-II) which enables the mobility-impaired people having limitations in upper extremities in carrying out daily activities in a better way. The device has seven degrees of freedom and side mount on a power wheelchair is used [18]. Fioretti et. al designed a navigation system which is integrated with a wheelchair and hence increases the autonomy of elderly people with motor disabilities [20]. Modularity in the assistive devices empowers the elderly people in living an independent and a better life.

39.5 Discussions

Co-morbidities is a common problem associated in the older generation, hence effective interventions are the utmost requirement of the society nowadays. Various assistive devices are presently available in the markets but many of them do not attribute comfort and diversity in its applicability to the older generation. Due to inability in performing the daily activities, a major portion of the elderly population is dependent on others, like their family members or caregivers. Although various facilities are already availed by many elderly people but many elder community dwelling in the remote and rural parts of India are deprived of these facilities. Designing such cost-effective and affordable equipments can ensure such people in living a better and independent life. The modular assistive devices extend the scope of its diversity and heighten its applicability. Designing such modularity in the assistive devices would benefit the older generation of the society in living an independent and fulfilling life.

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Chapter 40
A User-Centred Design Approach to Investigate the Design Parameters for Prescription Swimming Goggles

Aman Kumar and Dhananjay Singh Bisht

Abstract A survey-based study was conducted to find representative users with defective vision among students at a technical institute. Using a survey, it was found that 38 out of 95 student-swimmers suffered from various kinds of visual impairments and face problems that typically are not faced by a healthy swimmer during swimming. A combined study of literature and market analysis suggested that only a very few prescription swimming goggles (PSGs) are available in the market that satisfy visually impaired users. Even with the presence of these specialty goggles, there exist other user needs which have not yet been considered in the existing designs of PSGs. The aim of this paper is to employ a user-centred design (UCD) research for identifying physiological, physical/morphological and psychological problems faced by potential PSG users, and use the same to compile systematic schemes of design parameters for researchers and manufacturers interested in improvement of PSG designs.

40.1 Introduction

Swimming goggles can be categorized into two categories on the basis of their broad usage specifications: normal swimming goggles and prescription swimming goggles. Normal swimming goggles comprise of all the basic features such as cushion pad [1], anti-fog lens [2], adjustable straps [3] and adjustable nose bridge flange [4], whereas prescription swimming goggles include some prescribed features like UV protection lens, anti-allergic pad and power lens [5]. This research seeks to understand the various concerns while designing PSGs for visually impaired swimmers. It has been generally observed that only a very few makes of PSGs are available in the market while the population of visually impaired

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swimmers could be significant (it is about 40% of the total swimmers according to this study). It has also been observed that most swimmers from this user segment are not fully satisfied by the specifications of the available PSG goggles, and by using the existing goggles they often suffer from various types of physiological problems [6, 7]. It can also be observed from literature and market research that most swimming goggles are designed by considering chiefly the morphological and psychological factors only. The design trends suggest that these two factors dominate the product features in most existing swimming goggles, while the highly user-specific physiological factors are often ignored. Physiological factors should also be commonly considered for the design of PSGs.

In majority of cases, most face-based swimming accessories are designed with assumptions of normal, healthy and standardized populations. As a result, many products do not meet all the expectations of the users at large. A large section of the visually impaired swimmers is often likely to reject such standardized swimming wear as due to misfit and the dissatisfaction that ensues. In a user-centred design paradigm, it is essential to find out the problems and needs of swimmers belonging to this group of 'misfit users', precisely in order to make the designs of PSGs more effective and inclusive. Such paradigms of holistic understanding of design contexts help in the development of more rigorous and effective design processes. In this work, one such systematic methodology has been illustrated to investigate the design parameters and the related specifics of PSGs, in order to meet the essential needs of visually impaired swimmers.

40.2 Literature Based Study

To begin this work, relevant research works were examined to investigate the relevant frameworks and perspectives for PSG design [1–7]. The different design parameters of PSG designs were identified and classified into three categories for better semantics and easy usage during different design processes as described in Table 40.1.

Table 40.1 Parameter categories and the concerned areas of study for design of PSGs

Parameters	Concerned area of study
Physiological parameters	Effect of swimming environment on the health of swimmers. Concerns with the physiological impact of the environment on the user and damage to soft body parts
Morphological parameters	Concerns with the product morphology and face/head features and anthropometry
Psychological parameters	These are often difficult to observe, but perceived intuitively by swimmers

40.2.1 Study of Physiological Parameters

Some interesting investigations have been conducted by researchers in the past. In a test performed on the eyes of the 50 subjects just before and after swimming, it was found that 68% subjects were affected by the chlorinated pool water [8]. Ocular irritation is a well-recognized issue, but in general an accepted phenomenon is associated with swimming experience. However, very few people realize that this irritation may be a symptom of corneal edema. In this study, punctate and linear corneal epithelial erosions were identified through slit lamp test. It was concluded that various factors—chlorine concentration, pH of swimming pool water, tonicity of water, mechanical interruption and chlorine derived compounds were responsible for corneal changes and eye irritation.

Formation of disinfection by-products (DBPs) in the pool water was studied in another research [9]. It was found that the main cause of eye irritation was not just chlorine as such, but the compounds of chlorine and ammonia that were interfused into the water. The swimming pool water is generally polluted by synthetic chemicals, cosmetic organic materials, human body wastes (urine, skin particle, mucus, hair, perspiration, etc.) and other types of biota. It was reported that nitrogen compounds excreted by the swimmers in the pool water were the major source of DBPs. In a regular context, 13.212 gmL-1 nitrogen compounds were found in pool water in the form of sweat and urine. DBPs are categorized by their formation processes and ingredients such as chlorinated DBPs, organic matter DBPs and non-halogenic compounds of organic matter. Some of the injurious DBPs that are found usually dissolved in the air/water are—(1) chloramines; (2) tri-halomethanes (THMs); and (3) haloacetic acids (HAAs). According to this study, the concentration of compounds of chlorine was 2–20 times more than brominated compounds in the pool water. The study claims that eye irritation was suspected on the chloramines which had major role in development of ophthalmic diseases.

Effects of tap and swimming pool water on the surface of ocular epithelium of the human eye were studied in another research work [10]. It was found that chlorine was a dominant factor in irritation of eyes, and that the ocular epithelium surface can be damaged by direct contact of the eye with chlorine. It was also observed that problems such as eye irritation, redness and itching are the symptoms of several ophthalmic diseases like conjunctiva and keratitis. These may result due to the non-use of safety equipment such as the swimming goggles during swimming.

A physiological study also suggested that an elevated intraocular pressure (IOP) on human face causes an increased risk of glaucoma [6]. It was reported that the risk of damage to the optic nerves increases with IOP elevation. There are greater chances of facing glaucoma in situations where IOP elevation is high. In this study, examples of such activities were cited where the IOP increases or decreases. Swimming with goggles-on was one of such activities. It was reported that IOP elevates up to an equivalent of 48 mm of Hg while wearing swimming goggles. It was also claimed that especially those swimmers who suffer from any ophthalmic disorder, face greater risks of experiencing glaucoma. The physical structure of swimming goggles, frequency of their use and the duration of swimming were found to be important usability concerns for the visual impaired swimmers, because these factors are directly associated to the elevation of the IOP. Therefore, IOP elevation can be minimized by controlling and analyzing these factors and the related parameters.

40.2.2 Study of Morphological Parameters

Study of Product Architecture. Effect of several types of swimming goggles on IOP was studied in a past research [11]. Here, thirteen different goggle structures with different ocular areas were tested using applanation tonometry. Tests were performed for 20 min with each goggle and it was found that the ocular area and structure of goggles were the dominant concerns for IOP problem. It was also stated that the anatomical parameters also play an important role in design because these parameters vary from person to person. The study concluded that smaller sized goggles were prominently associated with increased IOP. It was recommended that goggles with large (mask type) structure can be used in place of smaller goggles to minimize the elevation in IOP.

The swimming mask may be an appropriate choice for those swimmers who are affected by glaucoma or other such ophthalmic disorders [7]. It was found that the use of large-framed structure led to lesser IOP increment. In smaller goggle, the structural frame is kept tensile through the relatively thin headband while in larger goggle the tension is distributed over a large area of the goggle as well as the contact surface of the ocular region. This leads to more even distribution of tensile forces, lesser build-up of peak pressure and better overall comfort.

A method to estimate the optimum protective area for goggles was demonstrated in another research work [12]. A laser equipment and face mannequin set-up was arranged to find out the required covered area which was identified by the help of digital sensing equipment. The minimum ocular area required for goggles was identified by investigating the covered facial landmarks.

An optical and mechanical stress test was performed to estimate the mechanical and optical properties of goggle lenses [13]. An experience of minimum optical aberrations was considered as a more important concern than the mechanical stress in this study. Mechanical properties were overlooked in favour of conformance to the favourable optical properties of goggle lenses. In this work, three different models of protective goggles were studied, and a theoretical model was prepared in advanced systems analysis program (ASAP) to test the goggles. A recommendation that followed was that the lens structure should contain prismatic shape and curved sphero-cylindrical structure with 2 mm thickness at the optical centre of the polycarbonate goggle lenses.

Study of Anthropometric. Necessities Anthropometry can be defined as the science of measurements of external human body parts in static or dynamic conditions [14]. Anthropometric study is usually performed when designing human-centred products for better interaction, usability, reliability and to avoid the material excesses in product structure. The body structure and the related work efficiency of every human being vary with gender, age, occupation, culture and geographical conditions. These also depend on the specific ways that users act and operate during work.

On the basis of the principle of 'body somatotypes', the human body structures can be classified as—endomorph, mesomorph and ectomorph [14]. A human body with mesomorph structure lies between the other two, and looks balanced, healthy and muscular. Bodies of most sportspersons could be said to belong in this category.

Swimmer head and face anthropometric data is necessary to investigate the design parameters for prescription swimming goggles (PSG). The landmarks for anthropometric measurement understood through the direct interaction between human face and the swimming goggles has been investigated in order to collect data for designing a PSG [15]. The measured dimensions are shown in Fig. 40.1. The different anthropometric dimensions used to design the PSG were—maximum cranial width or head breadth; minimum frontal width; maximum facial width or biorbital breadth; maximum cranial length or head length; cranial base width or bizygomatic length; upper facial depth; middle facial depth; nasal width or bialar breadth; nasal bridge breadth; nasal protrusion; nasal bridge height; nasal ala length; head circumference; forehead inclination; nasal length; and nasal bridge length.

40.2.3 Product-Related Human Perception: Cognitive Study

In a product design, human beings usually seek aesthetic pleasure and overall satisfaction in addition to the essential functionality [16]. Human perception of a service or a product may vary from person to person. Therefore, it is important to

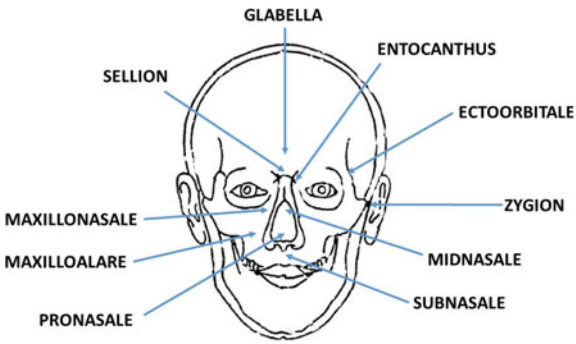

Fig. 40.1 Facial landmarks for anthropometric measurements

imagine the trade-offs and only then generalize the design attributes of a product in such a way that the maximum number of users should be satiated. As the satisfaction level of an individual is subjective, cognitive user study becomes important in design research. One such investigation of user perceptions about a product has been described through a case study involving translation of these perceptions into product specifications [16]. To gather responses from lead users about a product, often the design research begins by conducting interviews and questionnaire-based surveys. These user research activities help the design team to find out the needs, pain points and motivations of users. This is just one of the many ways in which human perception about a product plays an important role in design research works.

40.3 Methodology

As the project was related to the design of prescription swimming goggles, it was necessary to take visually impaired swimmers' opinions about this product and to understand the type of problems they faced with currently available goggles while swimming. Representative user responses were collected from visually impaired students through an open-ended survey. A compilation of their problems was performed while considering specifications from a market/user survey, and using literature. Specifications of the PSGs currently available in market were studied to understand the availability of solutions regarding the user problems.

As the aim was to design a prescription swimming goggles for visually impaired users, it was felt necessary to first identify the swimmers who were challenged with any kind of ophthalmic disorders. For this purpose, individual participants from the authors' institute were utilized. People who use spectacles and suffer from various ophthalmic disorders could be easily found in the institute's in-campus population of roughly 6000 students. The survey began by observing the activities of male swimmers in the institute swimming pool environment. Formal permission was requested and received from the pool management authorities to observe the pool-use scene, and also to offer the pool-going students a chance to participate as unpaid volunteers in this survey. Then, on the basis of a formal consent a total of 95 swimmers in the age group of 21–25 years took part in a preliminary survey which was conducted to find an approximate percentage of visually impaired swimmers among them. It was found that 38 out of the 95 swimmers suffered from some kind of visual problems, mostly afflicted by myopia or hypermetropia. These 38 swimmers were further investigated for the problems faced by them while swimming through structured a survey.

40.4 Results

40.4.1 Problems Identification from Market Segment

Formal interviews and open-ended questionnaires were used to collect the responses of 38 visually impaired student swimmers in relation to the problems faced by them. The 38 participants were selected as the representative sample of potential users for PSGs. Based on their responses, a hierarchy of their problems along with the respective frequencies of occurrence (in parenthesis) are listed as follows—flipping (28); visibility (27); fogging of lenses (25); field of vision (24); lens-scratching (22); burning around the eyes (20); leakage (17); pressure excessiveness (16); improper fit (15) and goggles color (8). From the responses (Fig. 40.2), it can be seen that 'flipping of goggles' was a major problem for swimmers and 28 swimmers mentioned facing this problem while diving and when applying strokes in water. This data was examined for identifying the primary (high priority) needs.

40.4.2 Problem Identification from Literature Survey

Flipping of goggles is a cause of water leakage. As a consequence of flipping, the pool water can enter the eyes of a swimmer. Pool water affects the normal functioning of eyes and can damage its sensitive internal parts. Therefore, it is very important for PSG designs to overcome the flipping problem especially since the visually impaired already suffer from a defective vision and any further damage could further cause severe visual disabilities. Small goggles are associated with cases of high intraocular pressure (IOP) on the eyes (Fig. 40.3).

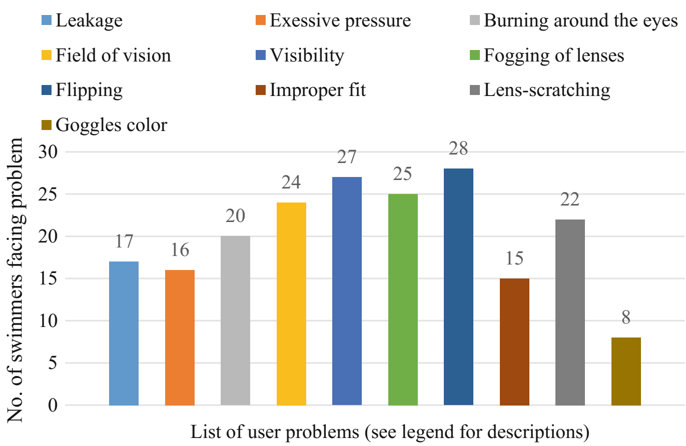

Fig. 40.2 PSG-related problems and their frequency

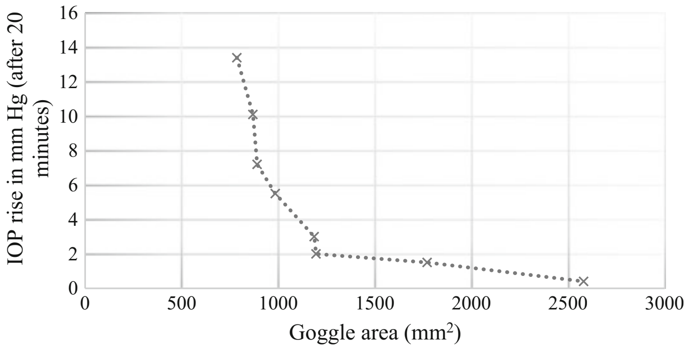

Fig. 40.3 Change in IOP after 20 min of swimming for different swimming goggles

Higher elevation in IOP is a major contributor to glaucoma in eyes [11] The chances of glaucoma in visually impaired people is found to be greater than that in people with healthy eyes. Therefore, IOP elevation is an important factor that needs to be incorporated in the design considerations of any PSG. In the same context, the goggle ocular area is a standard measure that directly affects the elevation in IOP and is therefore an important objective design concern.

40.4.3 Specifications Available in Existing Products

In order to come up with design specifications, 13 prescription swimming goggles (PSGs) which are currently available in market were comparatively studied and

Table 40.2 Available market solutions to PSG design problems

Hierarchical order of importance (ref. Fig. 40.2)	Design attribute/problem	Available solutions in existing PSGs e.g. [17–19]
1	Flipping	Not explicitly stated/available
2	Visibility	Power lens (mostly fixed type)
3	Fogging of lenses	Anti-fogging liquid and coating
4	Field of vision	HR:144°; VR:138° (maximum)
5	Lens-scratching	Scratch resistant coating
6	Burning around eyes	Soft cushion pad (silicone or foam)
7	Leakage	Pliable silicone pad
8	Pressure excessiveness	Suction pad
9	Improper fit	Availability of standard size
10	Goggle aesthetics	According to the category of swimmers

their specifications were examined in relation to the user responses. In the context of PSG design, an elaborate list of design-related problems along with their available solutions are provided in Table 40.2.

40.5 Discussion

The user research part of this work focused on a group of swimmers who suffered from some form of visual impairment. 38 visually impaired swimmers faced different problems while swimming. Apart from the dominant problems of flipping and visibility, it was found that many swimmers also faced the problem of fogging of the normal swimming goggles. Leakage of water, burning around the eyes, lesser field of vision, lens-scratching, flipping of goggles, improper fit to face and dissatisfaction with goggle aesthetics were other major problems faced by the swimmers.

Apart from this, some physiological factors were identified in literature. A higher elevation in intraocular pressure (IOP) has been considered a harmful factor that increases chances of glaucoma [11]. Various ophthalmic studies indicate that a higher IOP can damage and block ocular nerves. Wearing of swimming goggles could increase the IOP to approximately 48 mm Hg which is much higher than the normal value (12–22 mm Hg) [6]. Therefore, goggle-induced elevation of the IOP has been recognized as a major problem as a part of this research work's findings.

By comparing products, it was found that most PSGs have almost same configurations as that of the normal swimming goggles, with often times a common exception in terms of presence of power lenses in PSGs. Most of these power lenses were found to be of fixed type. In awareness with this, one of the future PSG design concerns could be towards provision of a removable lens assembly based on the specific user needs and context. Flipping was found to be another critical problem that can lead to leakage and subsequently harm to the user at a physical/physiological level. IOP elevation due to the goggle strap and its surface can be damaging to the eyes of swimmers, especially to those who are already suffering from vision defects. Therefore, specifications related to the IOP performance of a goggle should be made a standard design concern and mandatory information to be

Table 40.3 Prescribed target specifications associated with important PSG design concerns

S. No.	Design concerns	Target specifications
1	Flipping	Adhesive pad; interaction area; cushion pad; frame surface area and frame profile
2	Vision and visibility	Prescribed lens; lens material; lens profile and lens-attachments
3	IOP elevation	Interaction area; cushion pad; frame surface area; frame profile and strap adjustment

Table 40.4 Categorization of the PSG-related problems with corresponding design categories

Design parameters	User problems
Physiological parameters	Leakage through goggles; ocular area of goggles; visibility; pressure excessiveness and burning around eyes
Morphological parameters	Leakage through goggles; improper fit to face; flipping of goggles; lens-scratching; fogging of lenses; visibility and field of vision
Psychological parameters	Goggles colour and product architecture

displayed in the product packaging. With regard to implementing design improvements, some target specifications that should be considered in relation to the three critical PSG design concerns are listed Table 40.3.

40.6 Conclusion

In this study, three broad categories of design parameters namely physiological, morphological and psychological parameters have been examined in the context of PSG design. Intraocular Pressure (IOP), a physiological design concern was found to be one of the most important reasons for PSG related discomfort. Other physiological factors like burning around eyes, swelling of ocular nerves and punctuation of epithelium layer in the eyes should also be priority concerns while designing PSGs. On the basis of the different researches conducted during this work, a listing of the specific PSG design concerns have been provided in Table 40.4.

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Chapter 41
Attention of Viewers While Viewing Paintings Changes with the Different CCTs of Exhibition Light: A Quantitative Approach with Eye-Tracking Method

Amrita Bhattacharjee and Swati Pal

Abstract Light influences the appearance of paintings in any exhibition. Few studies have experimented with correlated colour temperature (CCT) and illuminance of light to understand the lighting preference of viewers while viewing paintings. However, effect of only CCT on viewers' perception is still a debatable issue. Also, previous studies in this regard have taken subjective approach with category rating that may lead to inconsistent conclusion. Therefore, a study has been designed with quantitative approach using eye-tracking method (N = 10) to verify the effect of different CCTs on viewers' attention. The experimental result shows that viewers' attention while viewing similar paintings changes with different CCTs of exhibition light having all other light parameters constant.

41.1 Introduction

Light influences the appearance of paintings in any exhibition. Light is a basic design element in interior design that is essential for presentation of fine arts [1]. In exhibition, spotlight is used to identify a painting on which attention is to be focused [2]. In 1941, Kruithof [3] conducted a study to reveal preferred combinations of illuminance and correlated colour temperature (CCT) for interior lighting conditions. Specifically, study of Kruithof revealed the lower and upper illuminance thresholds for a range of CCT within which the illumination is considered

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'pleasing'. Since now, several studies [4–13] have been done to verify Kruithof's graph among which some have been reported with inconsistent conclusions [14, 15]. Among all the studies based on validation of Kruithof graph, two studies have found that CCT has no significant effect on ratings of pleasantness [6, 7]. Another study on lighting condition for viewing painting has found out that viewer's preference has a negative correlation with CCT [13]. Nevertheless, a study on viewing paintings under LED illumination has concluded that CCT has significant effect on viewers' perception [11]. Therefore, whether alone CCT has any significant effect while viewing paintings need to be examined. In addition, a review of literature on Kruithof's graph [16] has mentioned that most of the studies in this regard have used category rating that may lead to inconsistent conclusion. The factors in the rating scale are always subjective, and different participants may interpret the terms in different ways based on their personal, social and situational factors [17]. So, as suggested by earlier researcher [16], a matching or discrimination task would lead towards more vigorous conclusions. For example, similar paintings can be exhibited at a time so that viewers can match or discriminate the light effect on them. In addition, as per knowledge, earlier studies in this regard have not taken quantitative approach. So, to address the research gaps, a study with quantitative approach has been designed to examine specifically the effect of different lamp CCTs (keeping all other light parameters constant) on viewers' attention while viewing similar kind of paintings. Eye-tracking method has been adopted as quantitative approach. The earlier study on attention of viewers revealed that eye movement is an apparent index to express the relation between what is observed and its relevance to the viewer's interest [18]. Data of eye-tracking will help to assess which painting is drawing more attention of viewers [19].So, in this experimental study, eye-tracking method has been considered as quantitative approach to verify the effect of CCTs on viewers' perception while viewing similar kind of paintings.

41.2 Methodology

In a mock-up gallery built in laboratory space of Department of Design, IIT Guwahati, paintings were exhibited under three different CCTs of LEDs keeping illuminance at constant level. In eye-tracking, gaze parameter has been considered for this study. Gaze is the sum of all fixation durations that helps to compare attention distribution among targets [20]. Therefore, data of gaze duration has been taken in account to assess in which painting (exhibited under different CCTs) viewers have paid more attention. The experimental design has been done following the experimental procedure that has been used to verify the effect of different exhibition lights on attention of viewers [19].

41.2.1 Experimental Design

41.2.1.1 Lighting Environment Set up

To verify the effect of CCT on attention of viewers while viewing paintings, a warm white (WW) LED (CCT = 2700 K), a cool white (CW) LED (CCT = 3500 K) and an artificial daylight (AD) LED (CCT = 6500 K) have been selected as illuminants. As in earlier study on viewers' attention, it has been noticed that viewers have preferred paintings exhibited under LED than under conventional halogen lamp [19]; so, for this experimental purpose, LEDs have been chosen as illuminants. Also, LED as exhibition light has comparatively less detrimental effects on paintings than other conventional light sources [21]. From the literature review, it has been found that conventional standards specify illuminance between 50 and 200 lx [22] that has been enshrined mostly based on surveys of practice across a set of major museums [23]. So, for this experimental purpose, the illuminance has been set at 100 lx which is in between this specified range. The measurements of vertical illuminance have been taken on centre point of plane of the exhibited paintings with standard Luxmeter (METRAVI 1332). The values of the light level on plane of paintings were controlled by varying the voltages through Variac (1-phase/ 0–270 V AC/1A). To avoid the influence of light on each other through reflection, black background was created. Also, as the goal of this experiment was to assess lighting, not evaluation of artwork, so, this black background helped the participants to concentrate on the appearance of paintings due to light effect.

41.2.1.2 Types of Paintings

According to the International Commission on Illumination (CIE), classification for light sensitivity of displayed materials in art galleries and museums, watercolour medium comes under highly susceptible displayed materials and oil medium under moderately susceptible displayed materials [24]. Following this classification, paintings from two different medium, i.e. water and oil have been selected as stimuli. Hence, three similar water-based paintings, i.e. poster colour paintings (11″ × 14″) and three similar oil-based paintings (12″ × 18″) drawn by professional painters have been chosen as stimuli. Similar paintings have been chosen to avoid any discrepancy between the stimuli from a particular medium. One sample of each types of painting is shown in Fig. 41.1, where Fig. 41.1a shows the sample of water-based paintings and Fig.41.1b shows the sample of oil-based paintings.

As the experiment is based on light effect on paintings, so, participants might get confused with the light and shadow effect of paintings itself has while viewing. Hence, to avoid any such confusion, flat colour paintings having no light and shadow effect have been chosen. In addition, the themes of the paintings were kept simple so that instead of judging the paintings, participants can concentrate on the appearances of paintings due to light effect.

(a) Water-based painting **(b)** Oil-based painting

Fig. 41.1 Samples of exhibited

41.2.1.3 Participants

Participants from fine arts and design background have been taken for this study. A total of 10 participants have been selected among which 5 participants were female and 5 were male. All of them belong to age group of 25–35 years having normal eyesight with no colour blindness.

41.2.1.4 Study Approach

As mentioned earlier, through eye-tracking method, quantitative study has been carried out to assess which CCT of exhibition light is drawing more attention of viewers while viewing similar kind of paintings. The data for eye-tracking was recorded by a senso-motoric mobile eye-tracking device (SMI ETG2 Wireless Analysis Pro). This device comes in eyeglass form, which increases the mobility of users, which in turn helps to increase the precision of recorded data. The binocular gaze data of participants was recorded. These recorded data was analysed through the software BeGaze3.0. Then, the gaze duration of individual participant for individual set of paintings under particular light has been calculated in milliseconds and the data was converted as fraction of total gaze duration for that set of paintings. For example, if Tw represents gaze duration of a particular participant for water-based painting under WW LED light, then,

$$\mathrm{Tw} = \frac{\text{Gaze duration for waterbased painting under WWLED}}{\text{Total gaze duration for waterbased paintings by particular participant}} \tag{41.1}$$

The calculated gaze values of individual participant for each painting exhibited under a particular LED have been compared. In this way, which LED has helped to draw more attention to the exhibited paintings has been observed.

41.2.2 Procedure

To simulate this experiment, a laboratory space was partitioned. Figure 41.2 shows the top view of the exhibition space. The position of paintings and light sources are also illustrated in Fig. 41.2.

To mitigate the daylight intervention with artificial light, the experiment was performed after sunset. As the experiment requires visual attention of participants, so, each of them was requested to avoid any eye-straining work on that day. Also, after coming to the experimental space, 5 min resting time was offered to each participant for relaxation. Within this time, participants were allowed to freely walk into the experimental space to become accustomed in simulated gallery environment. The experiment was performed in two steps. At first, three similar water-based paintings were exhibited. Each participant was asked to view the exhibited paintings and gaze durations were recorded through eye-tracking instrument. In next step, same procedure was repeated with three similar oil-based paintings.

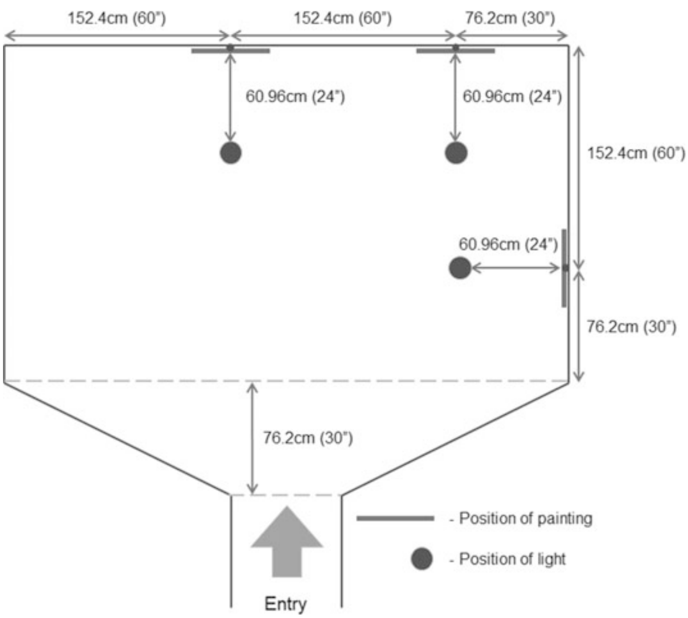

Fig. 41.2 Top view of exhibition space (not in scale)

Participants were free to move within the simulated exhibition area at the time of eye-tracking (Fig. 41.3). However, it was requested to keep 60 cm viewing distance from paintings to avoid shadow. Eventually, as there is no restriction on viewers' movement in galleries, so, it was intended to give utmost freedom of movements to the viewers within the simulated space.

The recorded gaze data was statistically analysed as discussed in the next section.

41.3 Results

41.3.1 *Effect of CCTs on Viewers' Attention While Viewing Water-Based Paintings*

Figure 41.4 shows the gaze data plot for water-based paintings. In the graph, *X*-axis represents different CCTs and *Y*-axis represents individual value of gaze data converted in fractional form. From Fig. 41.4, it can be observed that mean value of gaze duration for water-based painting illuminated by CW LED ($M_{\text{CWLED}} = 0.43$, SD = 0.069) is more than mean value of gaze duration for water-based painting illuminated by WW LED ($M_{\text{WWLED}} = 0.23$, SD = 0.069) and AD LED ($M_{\text{ADLED}} = 0.33$, SD = 0.069). So, water-based painting under CW LED has drawn more viewers' attention than the painting exhibited under WW LED and AD LED. It depicts that though the paintings were similar viewers have perceived it differently due to effect of different CCTs. Therefore, this result is revealing that

Fig. 41.3 Eye-tracking experiment

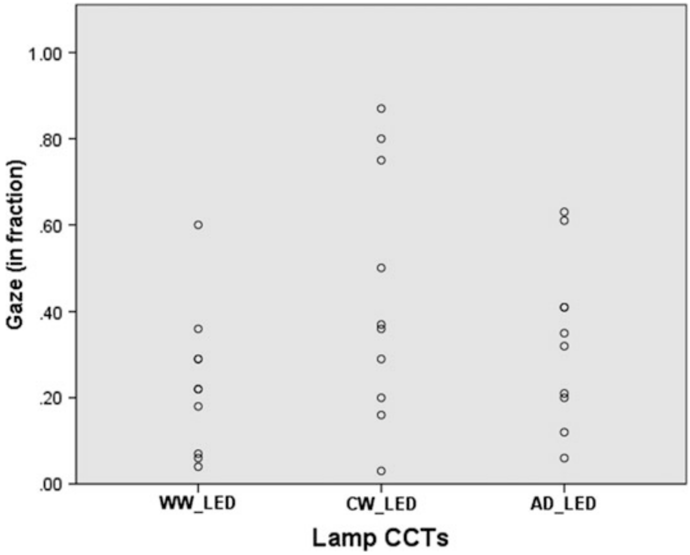

Fig. 41.4 Plot of gaze data for water-based paintings

attention of viewers while viewing water-based paintings changes with different CCTs of exhibition light (keeping other light parameters constant).

41.3.2 *Effect of CCTs on Viewers' Attention While Viewing Oil-Based Paintings*

To understand the effect of different CCTs on viewers' attention while viewing oil paintings, similar statistical analysis method has been followed. Figure 41.5 shows the plot of gaze data for oil paintings. In the graph, *X*-axis represents different CCTs and *Y*-axis represents individual value of gaze data converted in fractional form.

From Fig. 41.5, it can be observed that mean value of gaze duration for oil-based painting illuminated by CW LED ($M_{\mathrm{CWLED}} = 0.36$, SD = 0.069) is more than mean value of gaze duration for oil-based painting illuminated by WW LED ($M_{\mathrm{WWLED}} = 0.32$, SD = 0.069) and AD LED ($M_{\mathrm{ADLED}} = 0.33$, SD = 0.069). So, oil-based painting exhibited under CW LED has drawn more viewers' attention compared to the painting exhibited under WW LED and AD LED. It depicts that though the paintings were similar viewers have perceived it differently due to effect of different CCTs.

Therefore, the experimental results indicate that though the paintings and the light parameters (except CCT) for all the light sessions were same and constant attention distribution of viewers has differed depending on the different CCTs of exhibition light.

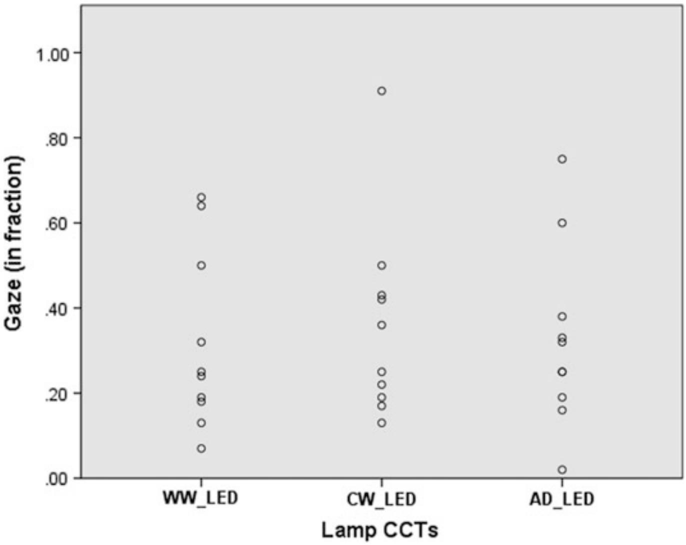

Fig. 41.5 Plot of gaze data for oil-based paintings

41.4 Discussion

The experimental results to verify the effect of CCT on attention of viewers while viewing paintings exhibited under LED lighting are suggesting that attention distribution differs based on different CCTs having illuminance at constant level. In addition, it has been seen by analysing the gaze data that paintings exhibited under CW LED has captured more attention than other two light sources. Therefore, earlier study concluding viewer's preference has a negative correlation with CCT [13] while viewing paintings can be partially agreed as because from this experimental result it has been seen that viewers have preferred CW LED to WW LED. Perhaps, similarity among the paintings has helped viewers to understand and differentiate the effect of CCT more precisely. Also, as it can be said that a quantitative research design [25] allows flexibility in treatment of data in terms of comparative analysis to verify reliability, so quantitative approach of this study might has led to a more precise and reliable conclusion.

Earlier study has argued that colour temperature of 3600 K is optimal for viewing artworks [22] as because at this point there is a change in preference for 'warm' or 'cool' lighting. Hence, in accordance with this, present study also showing that CW LED (CCT = 3500 K) having moderately cool or warm appearance is preferable by the observers. Moreover, difference in geographical factor leads to variation in colour preference [26] that may be applicable for preference of colour temperature of lamp also. Therefore, this present study will be completed if it is repeated in different tropical regions.

It has been seen by analysing the gaze data that, among three light sources, paintings exhibited under CW LED has captured highest attention, whereas paintings exhibited under WW LED has captured least attention for both water- and oil-based paintings. Therefore, different CCTs have effected attention of viewers while viewing paintings in similar way for both mediums of paintings considered in this present study.

The outcome of this present research can be applicable for lighting design in art exhibition to have better visual experience. Also, as a holistic approach, there is a need of further research with other lighting parameters (e.g. spectrum distribution, illuminance) to understand the viewers' preferred lighting conditions in art galleries.

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Chapter 42
Does Emotion Modulation Influence Speed–Accuracy Trade-off in Numerical Data Entry Task?

Shanu Shukla, Shrikant Salve and Pradeep Yammiyavar

Abstract It has been demonstrated that speed-accuracy trade-off (SAT) plays an important part in choice and decision analysis, but how emotion influences SAT is yet to be understood. SAT refers to the inverse relationship between speed and accuracy. It implies individual's willingness to increase either speed or accuracy; if one chooses to increase speed then accuracy often decreases, and if one increases accuracy then speed of the task decreases. The study investigates the effect of participant's emotion on SAT in numerical data entry task. The influence of induced emotion on SAT among the people (N = 48) familiar with number entry task has been studied experimentally through computerized data entry task. Positive, negative, and neutral emotions are induced through video clips and accordingly, their subjective emotional states are recorded through self-assessment Manikin (SAM) scale. Afterward, their performance is assessed on a computerized number entry task. The results suggest that there is no significantly observed difference in the trade-off performance between the participant groups with positive and neutral emotions. However, participants induced with negative emotion display reverse SAT effect, which implies a decrease in accuracy with a decrease in speed in numerical data entry task performance. These findings have significant implications in users-centered design research.

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42.1 Introduction

Emotion is a salient feature of human being; and so, it is important to scientifically understand its influence on human behavior. The effect of emotion on performance has been studied by several researchers [1–3] who have concluded that emotion contributes significantly to the performance of different tasks (For example, working memory task, decision making task, etc.). These studies, while reporting the effect of emotion on components of performance (i.e., speed and error), often ignored the capacity of emotion that can trade-off the speed/accuracy for optimal performance. So, it is important to peruse whether different emotion contributes to 'Speed–Accuracy Trade-off'or not. For human beings, assignments of daily importance are maximally influenced by the induction of emotion. One such assignment is that of 'number data entry' in which people are required to input numbers. The ubiquity of this task can be well experienced while operating mobile, typing, doing numerical calculations, entering personal identification numbers in ATMs and so on. The effect of emotion on number data entry is experimentally analyzed [4, 5] and emotion has been found to be a significant factor influencing human performance. However, these performance studies have ignored the influence of emotion on trade-off, if any, between the speed and the error components of performance. Consequently, they have failed to report whether the changes in emotion had its impact on speed–accuracy trade-off or not. The present paper demonstrates the result of an experiment which studies the effect of positive, negative, and neutral emotions on the speed–accuracy trade-off in numerical data entry task.

42.2 Emotion and Speed–Accuracy Trade-off

42.2.1 Emotions

Emotion is a temporary fleeting state that emerges from the environment, situation or person himself. Different emotional states subconsciously/consciously exert different effects on the information processing style of the person [6]. For instance, positive emotion signals the familiarity in the environment and hence directs the individual toward assimilative processing style. On the contrary, negative emotion identifies a challenging situation and hence calls for externally focused, bottom-up and accommodative processing style [6]. In another study, researchers [7] demonstrate that positive affect encourages interpretive or relational processing style and negative affect leads to detailed, stimulus-bound, or referential processing strategy. In terms of visual processing style, researchers [8] found that the positive emotion leads a person toward global processing where the focus is on the whole stimulus. On the other hand, a person induced by negative emotion focuses on a detailed or component part of the stimulus (called, local processing) [8]. To sum up this subsection, one can state that positive and negative emotions have a contrasted processing style—positive emotion activates individuals towards faster response in comparison with that rendered by negative emotion. This viewpoint, however, should be scrutinized under the lens of 'task contextualization'. In a study on motor and movement task, for instance, the reaction time of participants in a negative emotional state is seen to decrease as compared with those with the positive and neutral state [9]. Similar findings were highlighted in a study led by Coombes, Janelle, and Duley [10] in the performance of square tracing task where 'approach' and 'avoidance' behavior style were employed.

42.2.2 Speed–Accuracy Trade-off

The term 'Speed–Accuracy Trade-off (SAT)' implies that the individual speed capability increases with decrease in accuracy and vice versa while performing any task. In other words, it can be said that if speed is measured in terms of response time in seconds (i.e., increase in speed signifies a decrease in response time and vice versa) and accuracy in terms of errors committed (i.e., increase in accuracy signifies a decrease in errors and vice versa), then the SAT indicates an increase in response time will lead to a decrease in the number of errors.

Intuitively there is a small likelihood for an individual to perform a task with zero speed as well as perfect accuracy. There is, thus, a negotiation between maximum accuracy and minimum response time. According to the 'inbuilt trade-off approach' (as mentioned by Foster, Higgins and Bianoc, [11]), this decision in trading is believed to be universal as well as inbuilt in human behavior. Forster, Higgins, and Bianco [11], however, refute this idea in favor of a self-regulatory account of behavior in speed/accuracy tasks. They propose that human beings have different self-regulatory foci, either a prevention or promotion focus that influence speed/accuracy decision. In their model, they highlight that the pleasure, pain, and different motivational orientations can direct the people toward prevention or promotion goal states and hence result in SAT. It implies that SAT is dependent upon the individual's voluntarily strategic choices. However, the pertinent issue that has been ignored in their study is related to the emotion (positive or negative)-processing strategies which are, more or less, involuntarily or subconsciously controlled. As mentioned earlier, positive and negative emotions have different processing style; so, it can be assumed that different sets of emotions have the potential to influence the SAT. This assumption is supported by Frostman et al. [12] where the investigators suggested that it is not just 'voluntarily strategic choices' that produce SAT, but that person structural limitations, like 'age-related decrements in brain connectivity' also play a role in SAT. It reflects the physiological changes that accompanied in the brain influencing SAT. Since the emotion involves the physiological changes [13], there is a significant chance of both the different processing style and physiological changes in emotion influencing SAT.

42.2.3 Aim of the Experiment

The aim of the experiment is to study whether the induction of emotion among participants influences them to a trade-off between speed and accuracy or not in numerical data entry task. Here, emotions are categorized into three groups—positive, negative and neutral. Speed-accuracy is observed through ‘response time and error’ paradigm. It implies that if SAT functions, then increase in response time will lead to a decrease in error and vice versa.

42.2.4 Method

42.2.4.1 Participants

A total of 48 participants (Mean (M) = 25.61 years; Standard Deviation (SD) = 3.47; within the age range 20–30 years) voluntarily participated in the experiment. They were from the pool of people working in the coffee shop, grocery shop, and vegetable market. All the participants had an educational qualification up to 10th–12th standard and use computers or laptops for at least one hour in a week. To avoid any hemispheric-based affective differences, all left-handed participants were omitted from the statistical analysis.

42.2.4.2 Design

The study is a 3(Emotion: positive versus negative versus neutral) X 2(task condition: Restricted Time versus Unrestricted Time) mixed factorial design with the second factor as a within-group variable. The induction of positive, negative, and neutral emotion was done by showing the participant (any one of the) three video clips, e.g., violence video for negative emotion, comedy video for positive emotion, and a video compilation of geometric figures for neutral emotion. The duration of videos that were expected to induce positive or negative emotion was kept five minutes whereas that of neutral video was kept for two minutes and thirty seconds.[1] With respect to the task condition, the temporal duration for completing the task was manipulated. In case of the restricted time (RT), the fixed duration of 60 s was kept and in the unrestricted time (URT) it was left to the participants’ will to complete the task. The sequence/order of presentation of both the tasks was randomized among participants. Besides, in both the conditions participants were instructed to perform the task as accurately and as quickly as possible.

[1]This was done to avoid boredom among participants that could have arrived due to watching of neutral videos for a longer duration.

42.2.4.3 Material

To induce emotion in the participants, video clips were used and played on 15.4″ high-definition (HD) color screen. The videos were the short scenes selected from the local movies from that area (so as to be culturally relevant) on the theme of ‘violence’, ‘comedy’, and ‘geometry figure’. This induction of emotion among positive, negative and neutral group was subjectively recorded from the participants on two dimensions (i.e., valence and arousal) self-assessment Manikin (SAM) scale[2] [14]. Data entry task was conducted on a 15.4″ computer screen that was equipped with a Logitech keyboard. A computer-based calculator was used as an interface for the data entry task. An ‘informed consent form’,[3] and a ‘demographic questionnaire’ consisting of personal details, expertise in computers and other factual data of the participants were also recorded.

42.2.4.4 Procedure

The experiment took place in the strict laboratory condition at the Indian Institute of Technology Guwahati, India in a single sitting. Once arrived, participants signed the ‘informed consent’ and fill the questionnaire. After briefing about the SAM scale and the software interface for the data entry task they had been subjected to the practice trials (on interface and scale). They were then randomly allotted in any of the three experimental groups. The experiment consists of two sessions with a total duration of approximately 20 min. In the first session of ‘Emotion induction procedure’, participants were shown any of the three video clips (violence, comedy or geometric figure) according to their randomized allotted groups. The clips were of five minutes for a positive and a negative group and two minutes and thirty seconds for a neutral group.[4] Participant’s subjective emotional states were recorded on SAM scale before and after video presentations. After this session, an ‘Experimental Task’ session began. Here the participant had to work on ‘numerical data entry’ task in two blocks of RT (60 s) and URT conditions. The order of the task was randomly assigned and was the same in both the conditions. The participants were instructed to perform the task as accurately and quickly as possible. Data entry typing speed and errors on the number entry task were recorded through computer-based background recording.

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[2] A five-point rating scale. The valence ranges from happy/pleasant to depressed/unpleasant state. The arousal marks from a relaxed, sleepy state to an excited, wide-eyed state.

[3] Briefly detailing the structure of the study had been provided to the participants to get their written consent.

[4] Neutral video was kept shorter to avoid boredom that may aroused due to longer duration of viewing neutral video clip.

42.2.5 *Results*

42.2.5.1 Emotion Induction

A one way ANOVA has been carried out for Emotion: positive versus negative versus neutral on valence scale. The analysis revealed a significant effect of the valence scale ($F(2, 45) = 159.346$, MSE = 11.937, $p < 0.001$, $\eta_p^2 = 0.87$).

Fisher's least significant difference (LSD) reveals that positive emotion ($M = 4.5$) has significantly higher valence than negative ($M = 1.25$) and neutral ($M = 2.93$) emotion group. Similarly, there exists a significant difference between the negative and neutral emotions in terms of valence scale. Another one way ANOVA was carried out for emotion: positive versus negative versus neutral on arousal scale. The analysis revealed a significant effect on the three emotion states at the arousal scale ($F(2, 45) = 13.857$, MSE = 19.688, $p < 0.001$, $\eta_p^2 = 0.381$).

42.2.5.2 Analysis of Speed

An analysis of variance (ANOVA) has been carried out for 3 (*Emotion: positive versus negative versus neutral*) $\times$ 2 (*Task Condition: RT versus URT*) mixed factorial design with second factor as within group variable on speed of task performance which is taken as 'response time' in finishing the task within URT and RT. The analysis revealed a significant main effect of task condition ($F(1, 45) = 456.954$, MSE = 191,173.50, $p < 0.001$, $\eta_p^2 = 0.910$) and emotion ($F(2, 45) = 24.265$, MSE = 10,151.53, $p < 0.001$, $\eta_p^2 = 0.519$). Fisher's least significant difference (LSD) indicates that the (participants' induced with) negative emotion ($M = 190.187$) has significant higher response time as compared to those induced by positive ($M = 125.31$) and neutral emotion ($M = 132.25$) in URT condition. The response times of the participants within the latter two emotion groups (positive and neutral), on the other hand, differ negligibly. There was a significant interaction between emotion and task condition ($F(2, 45) = 24.265$, MSE = 10,151.53, $p < 0.001$, $\eta_p^2 = 0.519$) such that among the negative emotions, participants have taken more time in URT condition as compared to RT (Fig. 42.1).

42.2.5.3 Analysis of Accuracy

An ANOVA on number of errors committed by participants during task performance has been carried out and the result revealed no significant main effect of the task condition ($F(1, 45) = 0.549$, MSE = 9.375, $p = 0.463$, $\eta_p^2 = 0.012$). But, it shows a significant main effect of emotion ($F(2, 45) = 26.644$, MSE = 826.156, $p < 0.001$, $\eta_p^2 = 0.542$). Fisher's least significant difference (LSD) revealed that participants with negative emotion ($M = 12.781$) have committed significantly more errors as compared to those within positive (M = 4.469) and neutral emotion (M = 3.563) group. The number of errors committed by the participants within the latter two emotion groups (positive and neutral) differs negligibly. There is a significant interaction between the emotion and the task condition ($F(2, 45) = 6.262$, MSE = 106.969, $p = 0.004$, $\eta_p^2 = 0.218$) such that the participants within the negative emotion group have committed more errors under the URT condition than those committed under the RT condition. However, an opposite trend is observed within the positive and neutral emotion group (Fig. 42.2).

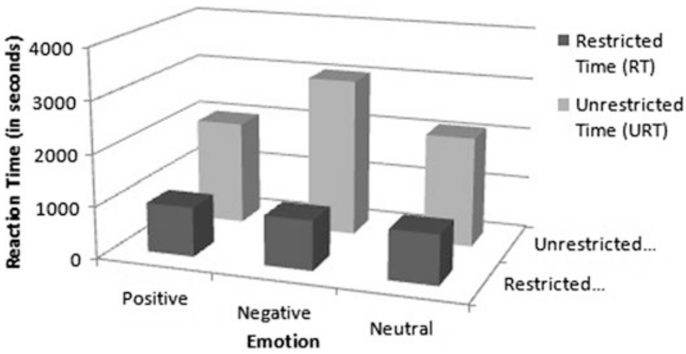

Fig. 42.1 Reaction time as a function of emotion and task condition

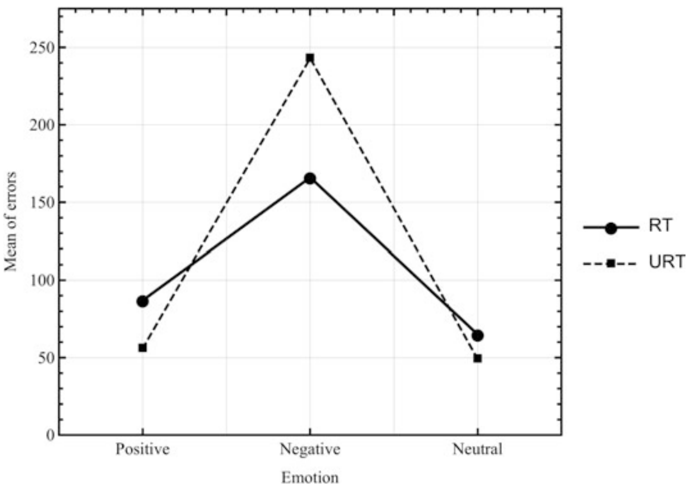

Fig. 42.2 Errors as a function of emotion and task condition

Table 42.1 Mean of errors and response time in emotion and task condition

Emotion	Task condition					
	Restricted time			Unrestricted time		
	Errors	Errors (in %)	Response time (in s)	Error	Errors (in %)	Response time (in s)
Positive	87	27.36	960	56	16.09	2005
Negative	166	52.20	960	243	69.83	3043
Neutral	65	20.44	960	49	14.08	2116
Total	318		2880	348		7164

42.2.5.4 Speed–Accuracy Trade-off

The errors and response time of 48 participants in different emotion and task condition are tabulated in Table 42.1.

The specific speed–accuracy trade-off in each emotional state is graphically displayed (in Fig.42.3). In Fig. 42.3, one can find that as the response time for positive emotion group increases from RT (960 s) to URT (2005 s), the number of errors decreases from 87 to 56 (almost 25%). Thus, it reflects a pattern of SAT, implies as speed decreases (increase in reaction time) accuracy increases (errors decreases). However, the decrease in error is not found out to be statistically significant at 0.05 level. Similarly, in case of neutral emotion group, as time increases from 960 to 2116 s., there is a drop in errors from 65 to 49 (almost 25%). This drop too does not reflect a statistically significant difference at 0.05 level.

Thus, in case of neutral and positive emotions, SAT trends display but it is not significant enough to draw clear implications of effect of emotion on SAT. In case of negative emotion, there is a sharp rise in the number of errors from 166 to 243

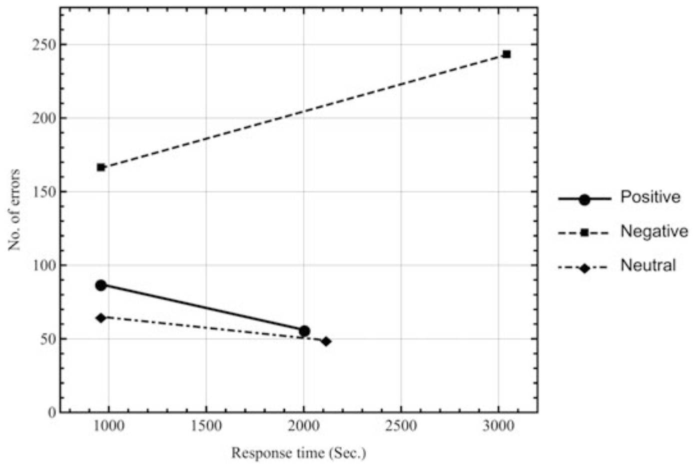

Fig. 42.3 Speed–accuracy trade-off graph

(***almost 47%)*** when response time increases from 960 to 3043 s. This contradicts the SAT trend and reflects the different pattern of SAT, i.e., as speed decreases, accuracy also decreases for the given tasks.

42.3 Discussion

The results of the emotion induction demonstrate that the video clips were successful in inducing emotion in participants and that experimental treatment had worked. As a consequence, there was a differential pattern of 'Speed–Accuracy Trade-off' in numerical data entry task. The overall results reveal that the positive and neutral emotions have a very low influence in bargaining between speed and accuracy when one is indulged in numerical data entry task. This means that under these emotions, individuals have no particular inclination to increase either speed or accuracy. This trade-off, if exists, will be accounted for some other reasons irrespective of positive and neutral emotion. Thus, the viewpoint that different processing styles and corresponding physiological changes produced by positive and neutral emotion can lend influence to SAT study may not hold true. However, in case of negative emotion, reverse pattern of SAT has been analyzed. It means that when response time increased, number of errors also shot up. The potential reason could have been that when time is more, individual is preoccupied with 'task unrelated thoughts' especially of negative stimuli and hence become error prone and take more time.

In sum, it can be said that emotions are not found out to be important factors influencing SAT. Future studies can pay special attention toward generating predictable patterns for the role of negative emotion in negotiation between speed and accuracy. The result of the study will have practical significance in the user-interface designing and human and system performance. For example, where the data entry requires both speed and accuracy (e.g., bank and health sectors), the graphic user-interface (GUI) can be in large visual formats with bigger font size, bigger table cell dimensions and by using contrasting colored backgrounds that necessitates attention for longer periods without emotional drain on the data entry operator. However, the study has certain limitations such as small sample size, and gender imbalance.

42.3.1 Conclusion

The study highlights that the negative emotion influences the number entry task (for instance, in bank and health sectors) in everyday lives. This suggests a serious implication when an individual takes longer time along with the increased number of errors. This may create a vicious cycle where an individual emotion may further deteriorate and leads to heightened frustration or anxiety. It may also excite an individual toward multitasking behavior which in the long run poses serious hazards to well-being and a decrement of performance [15, 16].

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Chapter 43
An Ergonomic Study: Bicycle Repairer in Rural India

Mohammed Rajik Khan, Nishant Kumar Singh and Digamber Shinde

Abstract The present study investigates the ergonomic risk factors associated with bicycle repairers in rural India. It aims to find a workplace design solution which can be easily implemented at low cost to avoid postural load during prolonged awkward postures adopted by this group of workers. The study comprises questionnaire survey and experimental task involving activities related to puncture repairing. In this process, stools of various heights, i.e., no stool, 100, 150, and 200 mm were utilized to avoid postural load during squatting posture. Out of the selected twenty-one repairers, four (04) were selected for the electromyographic (EMG) study of their longissimus muscle of the erector spinae while they perform the experimental tasks. The hand pain scores obtained for different hand regions of twenty-one repairers were recorded. Results show that the bicycle repairers are subjected to various ergonomic risk factors and using a stool of height 100 mm may minimize the postural load during repairing tasks and other works which involve squatting posture.

43.1 Introduction

Worldwide mechanization and industrial development have led to a majority of operations to be automatic and machine operated. However, people still perform many daily activities and jobs, i.e., house cleaning, washing of clothes, wall painting, material handling, repair and maintenance, agricultural works, etc., manually. It has been reported that the manual material handling (MMH) tasks may lead to the musculoskeletal disorders [1, 2]. Previous studies show that repetitive/

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prolonged adoption of working postures may cause musculoskeletal disorders (MSDs) [3–5]. The workers are often forced to adopt unnatural or poor postures due to product or hand tool design and work space layout [6, 7]. It is more difficult to control the working posture in comparison to the control of load weights or overexertion situation because working posture depends on workstation layout, work methods, and hand tool design [8]. Therefore, it is required to identify these causative factors and take preventive measures to eliminate them in order to avoid WMSDs. This will lead to less productivity and poor quality of work.

Among various unorganized sectors, bicycle repairer in rural India is one such group of workers subjected to ergonomic risks. Those workers carry out the task of bicycle repairing on the roadside without proper equipment and unfavorable work environment. Due to the indulgence of a significant part of Indian population in these sectors, there is a huge need for ergonomic interventions. The repairing and maintenance of bicycle involves cleaning, repairing of parts, painting, etc. In many countries this source of employment is not followed professionally [9] and thus there is a lack of studies on this trade. The lack of relevant studies on the ergonomic conditions of a bicycle repairer limits the proper understanding of the safety risks involved in the work demand of these workers.

Electromyography (EMG) is a diagnostic tool frequently used to study the neuro-muscular response to an activity. EMG can be performed both invasively and non-invasively using needle and surface electrode, respectively. EMG technique has been widely used for the analysis of the lower back muscles in both healthy individuals and individuals with lower back pain [7, 10, 11].

The present work investigates the ergonomic risk factors associated with the bicycle repairers residing in rural India and suggests a minimal cost workplace design solution which can be implemented easily on this group of unorganized sector workers. The result of this work is believed to act as a base for implementing design and ergonomic interventions in order to improve the health, productivity, and work efficiency of these workers.

43.2 Methodology

43.2.1 Participants

A study was conducted on twenty-one bicycle repairers from various bicycle maintenance shops across the city of Rourkela. The participants were selected randomly and subject to their acceptance for participation in this study. Institute ethical clearance has been taken for the study. The subjects were in sound physical health and were accustomed to manual material handling tasks. Table 43.1 summarizes the demographic characteristics of the participants. No woman was found working as a bicycle repairer, thus 100% of the subjects were male. The selected repairers were used to perform every possible maintenance work related to a

Table 43.1 Demographic characteristics of selected puncture repairers

Variable	Number (N = 21)	Percentage (%)
Age-group in years		
18–30	4	19.05
31–40	9	42.86
40–50	5	23.81
>50	2	9.52
Literacy level		
Illiterate	2	9.52
Primary school	15	71.43
High school	3	14.29
Degree	1	4.76
Years of experience in work		
Less than 1 year	1	4.76
1–5 years	5	23.81
5–10 years	10	47.62
Greater than 10 years	5	23.81
BMI range, kg/m^2		
Underweight (<18)	1	4.76
Normal weight(18–25)	8	38.10
Overweight(25–30)	9	42.86
Obesity(>30)	3	14.29

bicycle. All the subjects had at least 1 year of work experience in the field of bicycle repairing.

The anthropometric data (height and weight) of the participants were taken through a height-measuring scale and a weighing scale. Every participant was made familiar with the research purpose and the experimental tasks. They were asked to sign a consent form prior to the study. No compensation was involved in this study.

43.2.2 Questionnaire Study

Participants' information was collected by adopting a modified Nordic questionnaire. The questionnaire consists of questions such as age, weight, height, job experience, total punctures repaired daily, and personal preferences. The questionnaire also utilized Likert scale to evaluate hand pain index. It was a 5-point scale where 1 refers to no pain, 2-low/minor pain, 3-moderate pain, 4-high pain and 5-very high pain levels while using the conventional bicycle repairing tools. The questionnaire filling was administered by the research team.

43.2.3 Evaluation Tasks

Table 43.2 shows the steps involved in the experimental tasks to be performed by the participants selected for the EMG recording. The experiment starts with the positioning of the bicycle on the ground after the customer has parked it at the shop. The experiment ends with the repositioning of the bicycle such that it is ready to ride. The tasks were divided into six steps based on the significance of each steps.

Table 43.2 Puncture repair task steps

S.No.	Step	Description
1	Positioning of the bicycle	Performing manual material handling (MMH) to lay the bicycle horizontally on the ground
2	Dismounting of the tire tube	Deflating the tire and taking out the tire tube using tools
3	Locating puncture	Inflating the tube and checking puncture by dipping it into water such that bubble formation takes place (if any puncture presents)
4	Puncture repair	Repairing puncture by using conventional methods
5	Mounting of the tire tube	Inflating the tube and putting it back into the tire
6	Repositioning of the bicycle	Again performing MMH to put bicycle in the vertical position

Fig. 43.1 A bicycle repairer **a** locating puncture and **b** repairing puncture

The steps involved were based on the procedure followed by the puncture repairer while repairing a puncture. Figure 43.1 represents a bicycle repairer (a) locating puncture and (b) repairing puncture. The data were recorded for different stool heights in order to investigate the possible solution to prevent squatting posture, wherein no stool, 100, 150, and 200 mm height stools were considered.

43.2.4 Electromyography

Four (04) puncture repairers were selected for recording the EMG signal while performing the designed experimental tasks. The participants were selected on the basis that they were not suffering from any low back pain. The longissimus muscle of the erector spinae was examined while tasks were performed. It was selected for recording EMG because of its superficial position and its close association to low back pain. An in-laboratory fabricated single channel electromyography device was utilized for the recordings [12]. The participants were instructed properly about the equipment's before starting data recordings. Before signal acquiring, the skin at the muscle site was abraded by trimming hairs and cleaning with alcohol to make it suitable for recordings. The surface EMG electrodes (Ag-AgCl electrodes, Easytrode, India) were placed 30 mm lateral to L3 vertebrae [13]. The inter-electrode distance was kept 20 mm. Processus spinous of C7 was chosen to place the reference electrode.

The participants were asked to perform isometric maximal voluntary contraction (MVC) for longissimus muscle before the start of the data recording. For normalizing EMG signal, restricted back extension was performed with hands strapped at chest level. Three isometric maximal voluntary contractions were performed for 3 s each separated by a 1-minute gap. The highest surface EMG response during the activity was selected for the normalization.

The EMG recordings were band pass filtered at 28–742 Hz. The raw EMG data was sampled at 1000 Hz and amplified 1150 times. The quality of the signal was visually examined throughout the experiment. In case when excessive noise was present, the skin was again cleaned and electrodes were replaced with the new ones. Signal acquisition was done using a data acquisition module (USB 4704-AE, Advantech, Taiwan).

43.2.5 Data Processing

The signal processing was done using an in-lab developed program (LabVIEW 13.0, National Instruments, USA). The raw EMG signals acquired during the designed experiment were reduced into root mean square (RMS) signal by taking 200 ms window. The maximum EMG amplitude obtained during the isometric MVC activity was used to change the RMS signal in %MVC. The %MVC values were first added to get a total value and then it was averaged with respect to the total time steps for experimental tasks with no stool, 100, 150, and 200 mm stools. Afterward, average %MVC was calculated for each stool height. Finally, 4%MVC values were obtained.

43.3 Results and Discussion

The questionnaire study performed on twenty-one puncture repairers revealed that almost 90% of the participants were not satisfied with their present working environment. Right hand was the dominant hand for all. All the workers place bicycle on the ground for repairing purpose, use hands directly instead of tools, and never wears any sort of safety gloves while working. Putting bicycle on the ground will lead to the adoption of poor posture by repairers. Furthermore, using hands directly instead of tools or not wearing safety gloves while performing repair work may lead to injury. Such risk factors, if not dealt with on time may lead to work-related musculoskeletal disorders.

The questionnaire utilized a 5-point Likert scale to measure the hand pain index. The 5-point values adopted for measuring pain index were 1 (none), 2 (low/minor), 3 (moderate/significant), 4 (high), and 5 (very high). The hand was divided into nine (9) parts, namely thumb, index, middle, ring and small fingers, distal phalanx, middle phalanx, proximal phalanx, and wrist. The average values obtained have been represented through Fig. 43.2a, b for right and left hand, respectively. It was observed that thumb (3.524), index (3.429), middle (3.190), distal phalanx (3.286), and wrist (3.286) were the most affected parts of the right hand of workers. Also, thumb (3.238), index (3.143), and distal phalanx (3.000) were the most affected parts of left hand. The average values obtained for all the parts in both the hands were approximately 2 or higher which can be due to nonuse of safety gloves and use of hands instead of tools.

The questionnaire also consisted of a 5-point Likert scale to measure the sources of injury index rated by the participants based on their experience. The 5-point values adopted for measuring sources of discomfort index were same as used in pain index. The average values obtained have been presented in Fig. 43.3. The sources of discomfort considered were poor body posture, prolonged standing, prolonged squatting, lower back bending, repetitive motion, use of hand tools, and poor workplace design. The assessment revealed poor workplace design (3.857), lower back bending (3.476), and prolonged squatting (3.143) as the major sources of discomfort.

Considering the poor body postures of the bicycle puncture repairers, electromyography study was done to investigate the design intervention that should be adopted to decrease the extent of discomfort. Although bicycle repairers perform a number of repair works, the task sequence under consideration is generally adopted by them while repairing punctures. First, they were asked to perform isometric maximal voluntary contraction for normalizing of EMG data. Afterwards, EMG

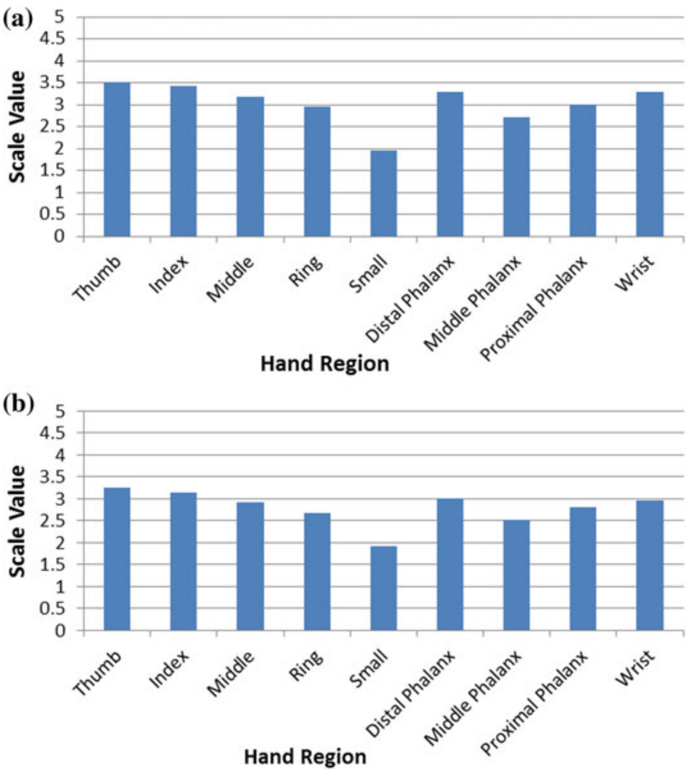

Fig. 43.2 Pain index recorded for **a** right hand and **b** left hand

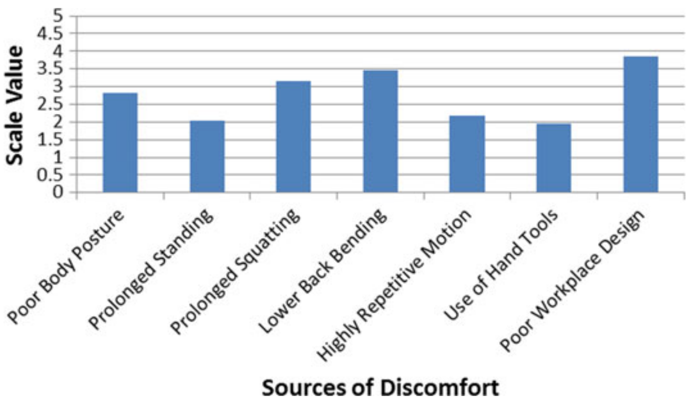

Fig. 43.3 Sources of discomfort score

data were recorded for the experimental tasks. The values obtained were changed into %MVC by dividing isometric maximal voluntary contraction value for each of the participants. The average %MVC value obtained for all the four participants was 13.4 when sitting in the squatting posture without the support of any stool. To test the suggested intervention, three different stool heights were tested. The heights were 100, 150, and 200 mm. The average %MVC obtained for 100 mm stool height was 7.77, while with 150 mm stool it was 15.133, and 16.986 while using 200 mm height stool. Thus, using a 100 mm stool while performing bicycle maintenance operations will decrease the back discomfort and may provide some support to the legs. The total time duration taken while performing the experimental tasks was recorded for all the participants under different stool setup. The lowest time recorded to complete the task was 294 s using 100 mm stool height, while the highest time was 368 s for 200 mm stool height.

43.4 Conclusion

The study concluded that bicycle repairers are subjected to various ergonomic risk factors such as awkward posture, poor workplace design, nonuse of hand gloves, and repetitive motion of the hands which can lead to work-related musculoskeletal disorders and may even cause workplace accidents. This group of unorganized sector workers is in immediate need of design and ergonomic interventions to counter aforementioned factors. Given below are some key outcomes and suggestions based on this study which must be implemented in order to move toward reducing the plight of the bicycle repairers:

- In any manual material handling, work involving squatting posture such as bicycle repair, gardening, agricultural work, and washing clothes use of stool is recommended.
- To increase the efficiency and productivity and reduce the level of discomfort due to squatting posture when the job is at ground level, a stool of 100 mm height should be used.
- A low cost, light weight, and easily portable stool having variable leg length must be developed which may act as a boon for workers who frequently adopt squatting posture.
- Hand gloves must be used by the bicycle repairers in order to negate high level of hand pain index.
- Ergonomic programs should be organized in every rural areas for bicycle repairers in order to enlighten them about do’s and don’ts at the workplace.
- A cohort study should be done on a larger group of rural bicycle repairers in order to get a better understanding of ergonomic risk factors associated to them and take preventive actions deem necessary to create a proper work environment.

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Chapter 44
Elderly Friendly Visual Communication Design: A User-Centric Approach for Guideline Formulation

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Aastha Bhardwaj and Saptarshi Kolay

Abstract Despite age being a factor, elderly in the working sector have increased productivity manifold. The purpose of this research was to enhance their readability using the knowledge of visual ergonomics, with respect to three paradigms—intangible interface, print media and signage. The first phase involved a screening interview where we identified major problems our target audience faced while dealing with the tasks at hand, as a part of an experimental analysis. Findings from these exercises were compared and evaluated. In the second phase, we mainly reviewed data from the India Readership Survey which covers a broad spectrum of categories—Media data, Indian Demographics, Indian Market. The end result is a design that has visual elements which are easy to see, provide assistance to individuals with specific visual needs, by incorporating only a relevant number of aspects into our research—visual displays and information design, visual perception and visual comfort.

44.1 Introduction

Just as our physical strength decreases with age, our eyes also exhibit an age-related decline in performance. Considering that the population of the elderly in the working sector would gradually be increasing in the coming years, technologies should be made such that they are in their favor—while incorporating user-centric design to resolve the problem areas. The kind and the style of fonts involved, the layout of the text are some of the many changes that can be brought about in order

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to improve readability. Good readability ensures good communication with the readers (users) and is one of the most important factor affecting efficiency and visual fatigue of one's work. Mostly, readability is referred to as speed and comfort of reading and being able to comprehend what is written and font type and size have a crucial role to play in the same. Different types of typefaces have varying levels of readability, and hence, the kind of typeface used depends on the kind of medium involved. This is where font psychology comes into play.

Just like greying of the hair, the eyes are also affected by age. The eye loses efficiency to focus while reading being of the loss of elasticity. The pupils shrink and as a result of which less light enters the eye. Other age-related diseases include glaucoma, cataract, partial to total loss in vision, macular degeneration—to name a few [1].

The above-mentioned factors are to be considered while designing media wherever interaction with the elderly is bound to happen—be it displays, print media or signage design.

44.2 Literature Review of the Case Studies

44.2.1 Human Factors Design Guidelines for the Elderly and People with Disabilities—Honeywell

Honeywell documented the collaboration of engineers and designers who circled around the needs of the elderly and people with disabilities in the area of design. After analyzing population demographics and taking interviews of the people with disabilities, they came up with affordable controls and products for the home and work environment, which according to them are usable or adaptable for all people, including the elderly and those with disabilities.

They explored various kinds of problems with the elderly and the disabled people including physical, perpetual and cognitive impairments, arthritis and multiple sclerosis.

Stating age-related effects on vision, their documentation also mentions statistics regarding acuity, dark sensation and sensitivity to light along with color vision, temporal resolution, depth perception and visual field [2].

Their solutions to the above-mentioned problems are unique to their research and have been thought upon keeping in mind the ease with which they can be brought into use, on a ground level and yet a different approach is required for the people in the working sector as this particular document does not revolve around people who are old and deal with printed matter and intangible interface as a part of their jobs.

44.2.2 India Readership Survey (Media Research Users Council)

India Readership Survey is one of India's largest readership surveys and collects a comprehensive range of demographic information and provides extensive coverage of consumer and product categories, including cars, household appliances, household durables, household care and personal care products, food and beverages, finance and holidays [3].

The purpose behind the formation of MRUC was to identify the need gaps in media research and provide pertinent solutions by adopting global standards in research techniques while maintaining integrity, fairness and reliability of the data and to release periodical research to capture frequent and rapid changes in media consumption. The Council is also responsible to keep a close eye on the evolving nature of media landscape and reinvent research techniques as and when required. A fine example of this would be how MRUC has embraced technology to maximize efficiency in its operations and to also ensure robust measurement. One of the Council's founding principles has been to uphold ethical practices in its operations and to be transparent with its members. Being an industry body, it firmly believes in fair play and encourages its stakeholders and members alike to endorse this philosophy [4].

44.2.3 Validating the MRUC 2017 Stats

The India Readership Survey for the 2017 was conducted by Nielson, covering a plethora of domains; right from the basics where they discuss the growth of households, the medium of education of the children, the growth in electrification of the Indian—to name a few, and then later discussing all the other aspects including print media trends, the growth in the number of readers since the last survey, growth across languages and increase in the listenership of the radio.

The data relevant to our research was basically regarding the key print media trends.

- Dailies have added 11 crore readers over the last 3 years (since the last survey)
- A 4% increase in readership was observed for age-group of people above 50, with a 7% rise of those who are literate and are in the working sector
- The Times of India and The Hindustan Times were the top 2 most read English dailies of all (out of the 10 English dailies mentioned within the survey)

44.3 Need of the Research and Paradigm Selection

44.3.1 Problem Statement

The main aim behind this research is to assist people with specific visual needs to ensure their comfort and improve overall performance by solving visual ergonomic problems. Visual ergonomics envelopes a vast number of domains of interest, of which only a generalized few will be taken into consideration for this research, such as visually demanding work-tasks and leisure activities, making it easier for the target audience to work with visual displays by reducing visual fatigue and catering to the needs of the people with aging vision. The first phase involves a screening interview and ethnographic surveys wherein we identify the major problems faced by our target audience by the assessment of tasks under the three paradigms of visual interaction. The second phase will see the validation of a secondary data, which is available as readership surveys and other recommendations for interactions with visual elements. The prime objective of the study is to collect readership information from a cross-section of individuals, in detail to present a true and unbiased picture of their readership habits. The deliverable of the research includes proposals for elderly friendly guidelines under these three visual paradigms.

44.3.2 Intangible Interface, Printed Media and Signage

Desk jobs require a good number of hours in front of a computer screen. Within this paradigm (intangible interface), the most commonly used mailing platform and a ticket booking site were taken into consideration for analysis of the current font style and its effect on the readability and work efficiency of the target audience.

It was found as a result of the surveys taken up in due course of the research that Gmail was widely used along with IRCTC.

When talking of printed media, India's most preferred English daily (according to India Readership Survey, 2017), The Times of India, was taken up as a part of the research along with The Hindustan Times which is currently the second most preferred English daily [3].

The part of the research that involves signage design for the elderly will basically be a validation of the existing signage in the Indian Institute of Technology, Roorkee, on the way-finding signage guidelines mentioned in the book "Wayfinding—People, Signs and Architecture" by Paul Arthur and Romedi Passini.

44.4 Methodology

The methodology followed within this research is depicted in the form of flowchart, which basically states that initial stages of the project involved going through and validation of existing case studies and surveys in the area of visual communication design for the elderly and a literature review of the same follows.

The need of the research is then stated along with the justification and selection of paradigms.

What then follow are the data collection—ground-level interviews with the target audience, surveying, examining the kind of font and the font style used in existing designs and giving the target audience a few tasks to deal with as a part of experimental analysis.

The analysis stage is based on the outcomes of the tasks and that also involves a comparison of the selected fonts and font layouts based on their *x*-heights, size and type (serif/sans serif).

Later on, a multivariate design is brought into the picture as a conclusion of targeting problem areas and solving them on the lines of user-centric design.

Appropriate guidelines are then formed as a result of the above processes, and the project will end with the final stage of user-testing for a thorough evaluation (Fig. 44.1).

44.5 Data Collection

44.5.1 Study Area

The study area taken up for one of the exercises is the Indian Institute of Technology, Roorkee, and the existing signage within the campus is taken up for the study which is in a standard blue board with white text on it.

44.5.2 Participants

A total of 40 participants (25 males and 15 females) were selected for the purpose of this study. The participants were aged in the range of 55–65 years (elderly who are nearing their retirement age). All the participants were working professionals with basic understanding of English and using computers (desktops, laptops) for checking their mails and booking railway tickets online.

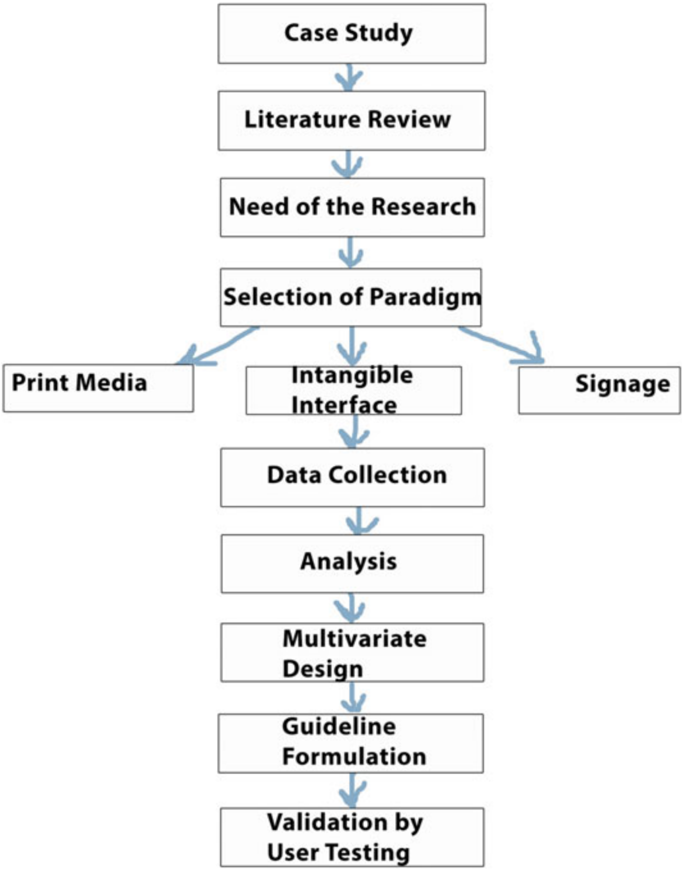


Fig. 44.1 Methodology flowchart

44.5.3 Survey Design

A survey was taken from the participants wherein they were asked questions regarding their preferences. The areas selected for questioning were as follows:

- Most commonly used mailing site
- Most commonly used railway ticketing Web site
- Views regarding the existing fonts on the above-mentioned sites
- Whether or not the text is comfortable to read in that particular size at a particular point of time or does it take away from the hierarchy
- Preferences between serif and sans serif fonts
- Whether they understand the difference between serif and sans serif and does that make any bit of a difference
- Views on the font size

- Whether or not they prefer having an elderly friendly mode being made available to them within the same Web sites
- Their most preferred English daily
- Most preferred newspaper columns
- Views on the font size, style (serif and sans serif) and color
- Whether or not does the font size have anything to do with keeping interest in reading their preferred articles
- Do they have a sort of a section-wise routine reading when it comes to reading the newspaper
- Do they skip through some sections while going back to certain others just to re-read them
- What keeps their interest going and whether or not the font has a key role to play in that

44.5.4 Experiment Design and Exercise

Two sets of experiments were given to the participants to perform for the intangible interface and the printed daily.

Within the English daily exercise, an original copy of the newspaper was given to the participants to read their favorite article. Once done, they were then asked to compare the above with the redesigned font size and style and to comment on the same.

A similar exercise was followed in the case of the intangible interface.

44.6 Redesign

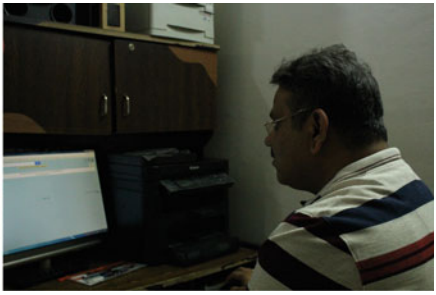
The redesigned solutions were such that the existing fonts within our selected paradigms were kept in mind and the suggested ideas were basically targeting the *x*-height of the fonts. The major deciding factor in any font is its *x*-height, and we largely wanted to play around that concept (Figs. 44.2, 44.3, 44.4, 44.5, 44.6, 44.7, 44.8, 44.9 and 44.10).

The offering-activity-culture map uses three ways to look at innovation opportunities: the "offerings" (products, services) with their functions and features, the "activities" people do with those offerings and the "cultural context" in which people use those offerings.

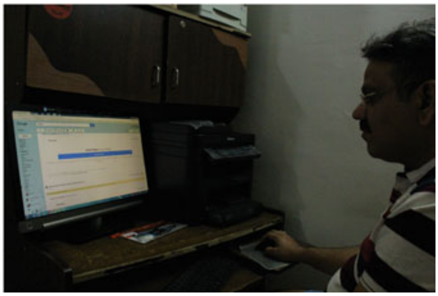
This method of mapping is quite effective, especially when aiming toward innovation that serves as something that connects with people.

Figs. 44.2, 44.3 Signboards; as seen from a distance (left) and from up close (right), within the campus of Indian Institute of Technology Roorkee (study area)

Figs. 44.4, 44.5 Signboards; as seen from a distance (left) and from up close (right), within the campus of Indian Institute of Technology Roorkee (study area)



Figs. 44.6, 44.7 Exercises under the paradigms of print media (left) and intangible interface (right)



Figs. 44.8, 44.9 Exercises under the paradigms of print media (left) and intangible interface (right)

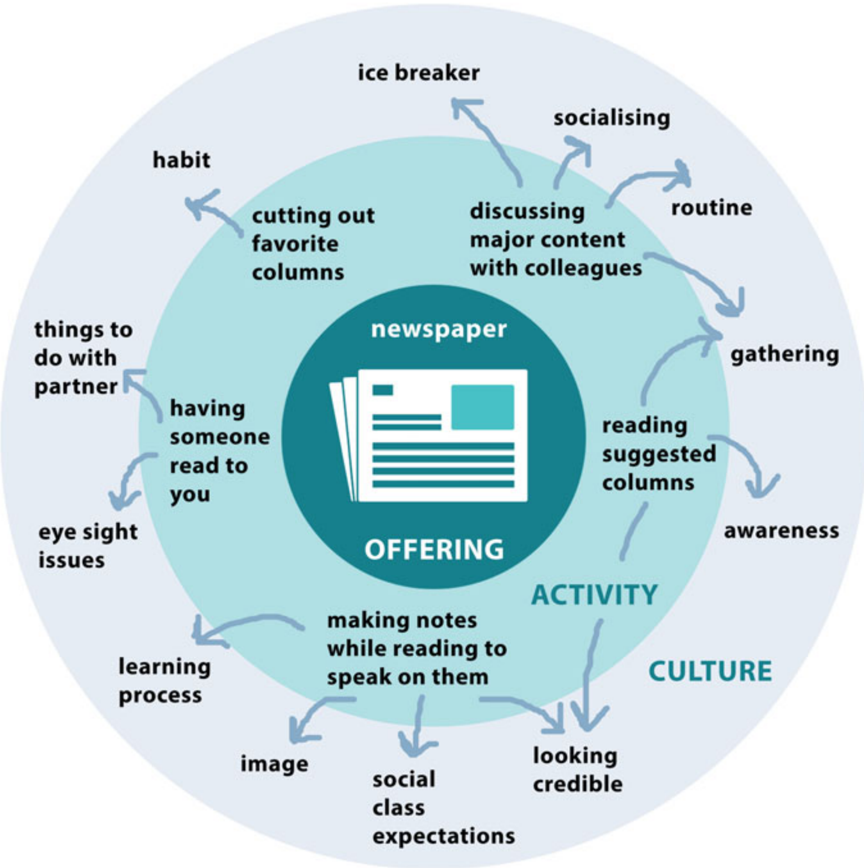


Fig. 44.10 Offering-activity-culture map

44.7 Data

Study of fonts was an essential part of this research. What kind of fonts are associated with what kind of emotion and how do they affect your readability and legibility altogether?

The participants of the survey were tested over a few established parameters, and the task at hand was to understand the current scenario; the most popular English dailies in the country, what font do they use and why? What kind of a thought was put into deciding the layout and how is the content managed? Whether or not fonts play a role in reducing visual fatigue and has aging anything to do with preferences in font styles?

- It was found that Times of India, one of India's leading English dailies, uses Times New Roman, Times Modern, Georgia and Verdana in its paper. Except Verdana, all the others are serif typefaces which are basically used to give eyes a fluent motion and a sense of reading a crisp text which flows across the length of the paper. Georgia is also considered one of the most beautiful typefaces because of the clarity it provides while reading.
- The second most appreciated English daily within the country, The Hindustan Times, uses Agate and Lipa Agate typefaces in its paper. These fonts were so designed to give clarity in the smallest font size possible, an ability which is many a time questionable when it comes to sans serif typefaces. Lipa Agate, in particular, saves up on a lot of space.
- Gmail, one of the most widely used mail all over the world and in India, uses Arial and Helvetica fonts in its interface.

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Chapter 45
Measurement of the Width of Ischial Tuberosity for Indian Male Motorcycle Users

Sai Praveen Velagapudi and Gaur Gopal Ray

Abstract The Ischial tuberosity or sitting bones bear the weight of the body when sitting. The width of the ischial tuberosity is, therefore, an important consideration when designing seats, especially narrow seats like bicycle and motorcycle. The aim of this study is to measure the width of ischial tuberosity for Indian male motorcycle users. The width of ischial tuberosity is measured using seat interface pressure map. Ischial tuberosity being a bony projection with very little tissue and muscle covering while sitting are clearly reflected as high pressure areas on a pressure map. A total of 63 male volunteers participated in this study. Seat pressure measurements are carried out for each subject while seated on a hard surface. The resulting data is analysed to measure the width of ischial tuberosity and its general statistical distribution. The results show that the mean width of ischial tuberosity is 111.8 mm with a standard deviation of 9.3 mm. The 5th and 95th percentile values are 97.3 and 127.8 mm, respectively. The dimension of ischial tuberosity can be the basis for defining the minimum width of seat required for narrow seats like bicycles and motorcycles.

45.1 Introduction

Motorcycles are extensively used for commuting in India [1] and other Asian countries with up to 85% of the households in these countries owning motorcycles [2]. The typical commute time in these countries is between 30 and 60 min one way [3]. Seating comfort therefore is an important requirement for motorcycle users in these countries. However, there is very less research on seating comfort of motorcycles despite several studies showing high discomfort in low back and

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Fig. 45.1 Comparison of Motorcycle and Passenger car seat

buttocks of motorcycle users [1, 4, 5]. The motorcycle seat is considerably narrow in comparison with typical office chairs or passenger car seats; Fig. 45.1 shows a comparison between a typical motorcycle seat and passenger car seat.

The seated hip width and the width of ischial tuberosity are two important anthropometric dimensions for design of a seat, and the later being the minimum criterion for, especially, narrow seats. There are published results for the seated hip width [6, 7] while there is no data on the width of ischial tuberosity. The Ischial tuberosity or sitting bones are defined as bony swelling on the posterior part of the superior ramus of the ischium in the pelvis bone [8] and bear the weight of the body when sitting. The aim of the current study is to measure the width of Ischial tuberosity of the pelvis bone for Indian males. The ischial tuberosity can be clearly located through a seat interface pressure map.

45.2 Methodology

The methodology described by Chen et al. [9] is adopted in this study to measure the width of ischial tuberosity.

45.2.1 Participants

A total of 63 male volunteers from TVS Motor Company, who regularly use motorcycles, participated in the study. Table 45.1 gives the general statistics of the participants in comparison with Indian motorcycle users [1] and general driving population in India [7]. The volunteers are clearly explained the details of the study

Table 45.1 General statistics of study sample

	Study sample $n = 63$		Motorcycle users $n = 178$, [8]		Indian population	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	31.4	10.3	30.7	6.6		
Height (cm)	172.0	7.3	173	8.9	167.3	6.8
Weight (kg)	71.1	9.7	73.3	11.3	63.9	12.4

before the start of study, and a written consent is obtained from them. All the volunteers use motorcycles regularly and none of them have any history of musculoskeletal disorders. The entire research is approved by the human resource department of TVS Motor Company and complies with the work ethics of the organization.

45.2.2 Procedure

The measurement of ischial tuberosity is carried out using seat interface pressure on a hard surface following the methodology used by Chen et al. [7]. Figure 45.2 shows the experimental set-up. Ischial tuberosity being a bony projection with very little tissue and muscle covering are clearly reflected as high pressure areas on a pressure map while in a seated posture. Seat pressure measurements are carried out for each subject for a duration of 30 s using a pressure mat from Teckscan. The pressure mat, measuring 300 mm $\times$ 300 mm, consists of 400 piezoresistive pressure sensors in a 20 $\times$ 20 matrix. The pressure mat is equilibrated and calibrated before measurements as prescribed by the manufacturer.

45.2.3 Data Analysis

Figure 45.3 below shows a typical pressure distribution of one of the subjects. The figure shows pressure intensities of different levels in different colours ranging from blue, for pressures greater than 0.3 kPa, to red for pressures greater than 11 kPa. The area of the figure in white shows no contact between the seat and the body. The width of ischial tuberosity is derived from the seat interface pressure measurements as indicated in Fig. 45.3.

The data is analysed to obtain the mean, median, standard deviation and various percentile data. Further, the data is also analysed to understand the influence of age, height and weight on the width of ischial tuberosity using Pearsons' correlation test. Microsoft excel and IBM SPSS software packages are used for the analysis of the data, and the correlations are considered significant based on the statistical significance of Pearsons' correlation coefficient r.

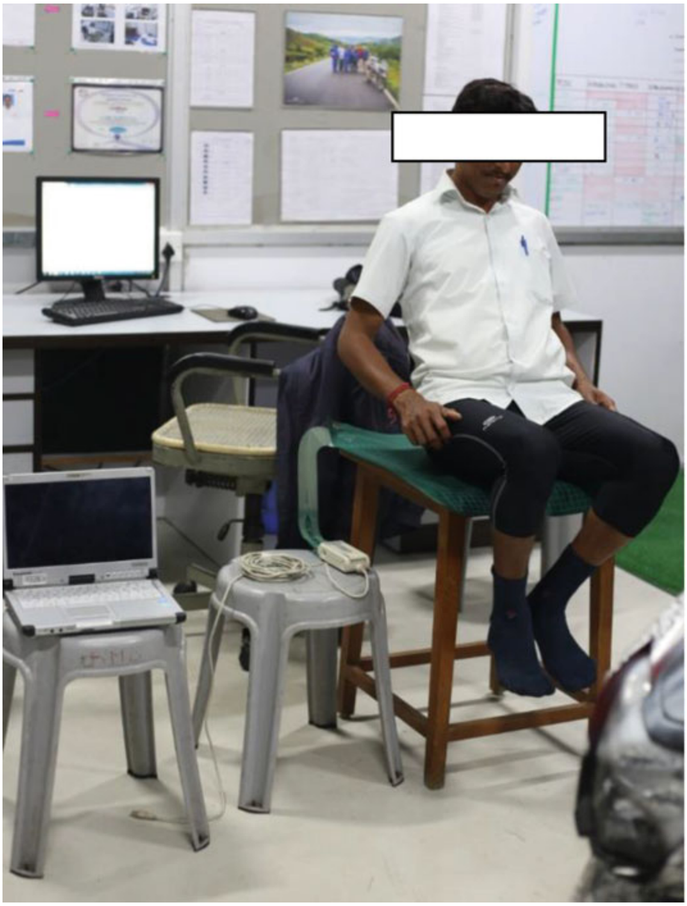

Fig. 45.2 Measurement set-up

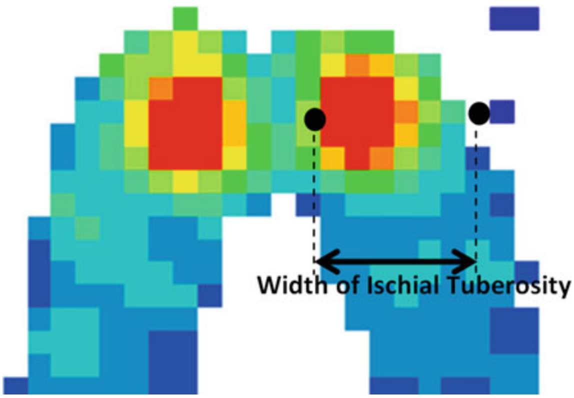

Fig. 45.3 Typical pressure map indicating the measurement

45.3 Results

The minimum width of ischial tuberosity measured in the study sample is 91 mm while the maximum width is 141 mm; Fig. 45.4 shows the distribution of data. The mean of width of ischial tuberosity is about 111.8 mm; Table 45.2 gives the other statistical values for the width of ischial tuberosity.

The results of the Pearsons' correlation test show that there is a significant correlation between the width of ischial tuberosity and weight as well as height while there is no significant correlation with age. Table 45.3 shows the correlation coefficients (Pearsons' **r**) along with their statistical significance while Figs. 45.5, 45.6 and 45.7 show the scatter plot between width of ischial tuberosity and weight, height and age, respectively.

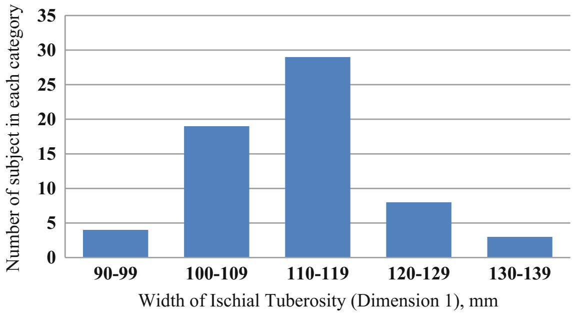

Fig. 45.4 Distribution of width of ischial tuberosity in study sample (n = 63)

Table 45.2 General statistics of width of ischial tuberosity

	Width of Ischial Tuberosity (n = 63)
Mean	111.8
SD	9.3
5th Percentile	97.3
50th Percentile	112.0
95th Percentile	127.8

Table 45.3 Correlation coefficients between age, height, weight and width of ischial tuberosity

	Correlation coefficient with width of Ischial Tuberosity (Pearsons' r)
Weight	0.802**
Height	0.714**
Age	0.228

*Significant at $p < 0.05$
**Significant at $p < 0.01$

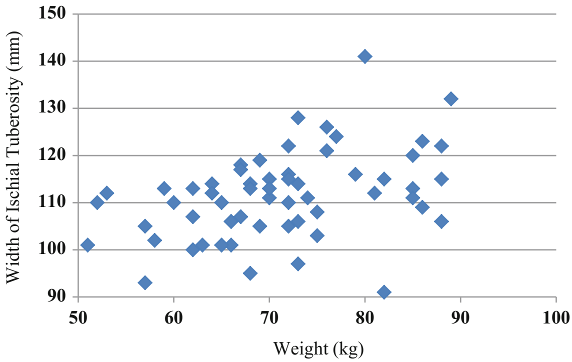

Fig. 45.5 Distribution of outer of peak pressure zone in study sample (n = 63)

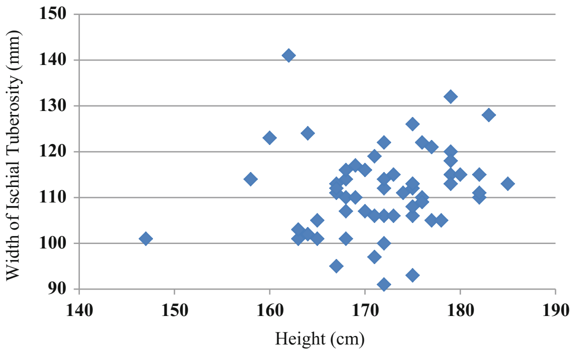

Fig. 45.6 Distribution of outer of peak pressure zone in study sample (n = 63)

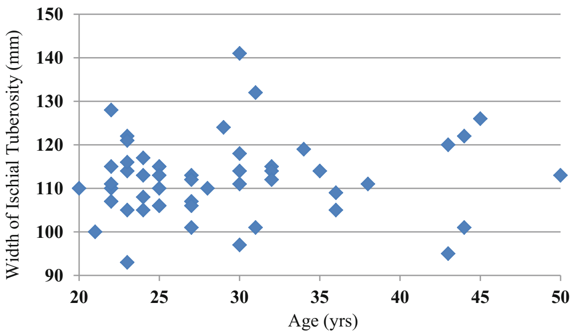

Fig. 45.7 Distribution of outer of peak pressure zone in study sample (n = 63)

45.4 Discussion

The width of ischial tuberosity is an important consideration for the design of seats in vehicles with narrow seats such as motorcycles and bicycles. India is one of the largest motorcycle markets in the world, yet there are no studies that provide the width of ischial tuberosity for Indian motorcycle users. This study gives an estimate of the width of ischial tuberosity for Indian motorcycle users. The results show that the mean width of ischial tuberosity is 111.8 mm which is lower than the value reported for Taiwanese [9], however, the study by Chen et al. [9] uses a small sample size of 15 people. The results also show a strong correlation between height as well as weight with the width of ischial tuberosity which is expected as most anthropometric dimensions in the body have a strong positive correlation with height and weight.

This study is carried out with a sample size of 63 working at TVS Motor Company (Hosur) and therefore limited in terms of sample size as well as geographical distribution. However, the results provide a good initial estimate of the width of ischial tuberosity which is an important input for design. The method for measurement of the width of Ischial tuberosity is derived from Chen et al. [9] and is an indirect one; it is possible to improve the accuracy by using more direct measurements of the width of ischial tuberosity through radiographic or magnetic resonance imaging, however, may be very expensive and not very safe for the participants.

45.5 Conclusions

This study has reported the width of ischial tuberosity for Indian male motorcycle users with a study sample of 63. The mean width of ischial tuberosity is 111.8 mm while the 5th and 95th percentile values are, respectively, 97.3 mm and 127.8 mm. This study provides useful inputs for the design of motorcycle and bicycle seats for India.

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Chapter 46
Awareness, Availability, and Accessibility of Assistive Technologies for the Elderly in India: A Review

Charu M. Maurya, Nitin Maurya and Amarendra Kumar Das

Abstract Old age is associated with various biological and functional changes, which result in physical frailty, onset of diseases, memory loss, etc, in the elderly. Thus, they face lots of difficulties in their daily activities, which make them dependent on others. To facilitate the elderly in their daily activities independently with ease and comfort, assistive technologies (ATs) have proven to be effective. But AT industry, specifically in India, currently remains limited and specialized. Following a systematic approach to review papers/research articles on the subject, an effort has been made to understand the current status of AT industry in India especially with respect to the issues of awareness, availability, and accessibility. The review highlights the availability of mobility aids, hearing, and visual aids for the elderly in India, but there is need to develop and create awareness about other kinds of assistive aids like aids for dressing, self-care, communication, and leisure activities for the elderly. Appropriate ATs not only can help alleviate the problems faced by the Indian elderly but also create a market segment, which largely remains untapped right now. The review also highlights ATs like a multipurpose wheelchair, which also assists in defecation, cleaning, and changing of clothes, a chair with shower system for elderly to take bath independently, a device for managing urinary incontinence, modified wheelchair that can be converted into crutches. But the majority of these aids are at the prototype stage and are not being manufactured. The review, while identifying areas of future research on ATs in India, also urges entrepreneurs to come forward and engage with the researchers so that the benefit of their research can actually reach the elderly.

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46.1 Introduction

The global population of people aged 60 years and above is estimated to double from 900 million in 2015 to about 2 billion in 2050 [1]. A growing elderly population necessitates appropriate actions to address various issues related to health, mobility, and well-being of the elderly, many of which are apparent and/or may be imminent.

46.1.1 Old Age: Health and Activity Restriction

Old age is commonly associated with onset of diseases, frailty, and memory loss due to various biological and functional changes. Deterioration in motor functions with increasing age, especially certain parameters such as balance, flexibility, and strength, makes senior citizen dependent for the simplest activities of daily living (ADL) [2, 3] Elderly, particularly those 80 years and above face problems in bathing, toileting, dressing, and transferring [4]. The fear of falling is another factor that restricts activities in old age [5, 6] with the risk factors being physical frailty, perception of poor health, obesity, cognitive impairment, depression, poor balance, and history of at least one fall [7].

46.1.2 Providing Care to Elderly

Elderly need care and assistance especially if they have difficulty in performing their daily task. Assistance can be provided by family members, paid assistant, and institutional care. Support by family members has never been a problem in India where a value-based joint family system was dominant but changing family patterns, social norms and values, disintegration of joint family setup, urbanization have today made the elderly more prone to isolation and abandonment [8, 9]. Assistance from a paid person may not be affordable to everyone. Institutional care is another way to help senior citizens but the elderly do not like to stay in old age homes [10]. In such a scenario, an elder-friendly home environment and assistive technologies (ATs) have proved beneficial.

46.1.3 Assistive Technology Meaning and Impact

World Health Organization defines 'assistive technology' as 'those devices whose purpose is to maintain or improve an individual's functioning and independence to facilitate participation and to enhance overall well-being' [11]. The availability of

ATs to fulfill activities of daily living increases self-reliance among the elderly. Improvement in social status, self-esteem, not being burden to others, improved well-being, and economic situation is among the other achieved benefits of ATs [12]. Video monitoring, remote health monitoring, electronic sensors, and equipment such as fall detectors, door monitors, bed alerts, pressure mats are some of the ATs which can improve safety and security of elderly at home [13]. ATs can also reduce the costs of care for the elderly and their families [14].

46.1.4 Assistive Technology in Indian Scenario

While there are many documented benefits of ATs, the AT industry currently remains limited and specialized, producing products that primarily serve high-income markets. Elderly in low- and middle-income countries are not getting proper benefit because of high cost, inappropriate design and fitting, not catering to actual needs, failure of a service infrastructure to produce and maintain devices, and the absence of properly trained workforce [1]. Thus, present review article explores the status of awareness, availability, and accessibility of assistive technologies for the elderly in India.

46.2 Method and Material

A systematic approach was followed to retrieve papers/research articles focused on awareness, availability, accessibility, and needs of assistive technologies for activities of daily living (ADL) by elderly (60 years and above) in India. The electronic databases searched included Google Scholar, PubMed, ScienceDirect, MEDLINE, EBSCOhost, Scopus, and JSTOR. Literature during the period of 2000–2018 published in peer-reviewed journals and conference proceedings in English was selected for the review. The search terms 'assistive aids,' 'help aids,' 'assistive technology,' 'rehabilitation aids,' 'self-help devices,' 'enabling aids' were used in combination with 'elderly,' 'senior citizen,' 'old age,' 'activities of daily living,' 'instrumental activities of daily living.'

Papers pertaining to assistive aids useful to elderly for doing activities of daily living (bathing, dressing, toileting, transferring, feeding) and instrumental activities of daily living (housekeeping, food preparation, communication, taking care of medicine) in Indian context were selected for final review. Reference list of selected papers was searched, and papers that met the selection criteria were also selected.

Identified articles were categorized according to the purpose of the study. The review focuses on awareness, needs, and challenges in the field of assistive aids for doing ADL and IADL in India. Innovation and research undertaken in the area were also emphasized. Web portals of Government of India and its institutions were also referred to obtain information related to accessibility and availability of ATs in India.

46.3 Results and Discussion

46.3.1 Necessity of Assistive Technologies for the Elderly in Indian Context

Old age is associated with various forms of disability due to weaker senses, poor physical, and mental health [15–17]. Nearly 85% of the elderly population in India suffers from hypertension, cataract, osteoarthritis, chronic obstructive pulmonary disease, ischemic heart disease (IHD), diabetes mellitus, benign prostatic hypertrophy, upper and lower gastrointestinal dysmotility (dyspepsia and constipation) and depression, as found in a survey jointly conducted by World Health Organization and Government of India [18].

According to Census of India (2011), one in every twenty Indian citizens aged 60 years and above is either physically or mentally disabled. The disability rates were higher among males than females and in rural areas as compared to urban areas [19–21]. Impairment and disability affect health-related quality of life [22] and limit the activities performed by elderly specifically after 70 years of age [17]. With increasing age, dependency also increases as elderly face difficulty in bathing, dressing, toileting, continence, and feeding [4, 23]. Walking outside the house, cooking or cleaning, climbing stairs, getting up from a sitting position, etc, are other activities, which the elderly found as difficult [16, 24]. Apart from the age-related changes, many a times the interior architectural defects in the homes where elderly live also restrict their movement and activities and result in avoidable accidents [25, 26].

The scope of technology intervention, for assisting elderly in maintaining independent life and improving delivery of health services, has been highlighted by World Health Organization in their bulletin [27]. Other benefits of technology intervention for elderly in the areas of health and nutrition (culture-specific nutritional recipes, educational material for enhancing knowledge, and skill pertaining to nutritional care), design (barrier-free environment, enabling devices for doing ADLS, clothing), networking, entertainment, recreation, entrepreneurship, and income generation have also been reported [28]. The above discussion clearly illustrates that assistive aids are beneficial in providing independent and comfortable life to elderly.

46.3.2 Awareness Regarding Assistive Technologies Among the Indian Elderly

Indian elderly are taking benefits of many assistive aids available in the market. Many elderly, even though illiterate or less educated, have been using assistive devices like spectacles, hearing aid, walking sticks, kneecaps, and lumber belts [29]. Malhotra et al. also observed elderly using spectacles and hearing aids. Walking stick was found to be the most commonly used aid [17].

Kumar et al. in a survey on the elderly analyzed the awareness level and their willingness to use the assistive aids. The survey yielded that the awareness level among the elderly was high for communication, mobility, and ADL devices, whereas low response was found for the clothing aids (Velcro clothing, pressure modification stockings), followed by footwear (Velcro fastening shoes), furniture, and kitchen gadgets. The devices for which the awareness level was observed to be high such as walking aids, vision aids, grab bars, raised seats; medicine dispenser had low utilization among the respondents. They were found not to be willing to use such aids as these had little sociocultural acceptance. But the elderly showed interest for dressing aids, kitchen gadgets, and home security systems, provided these are made available to them at an affordable cost [30].

46.3.3 Availability and Accessibility of Assistive Technologies in India

Number of manufacturers and suppliers produce market-assistive devices for the elderly in India. Artificial Limbs Manufacturing Corporation of India (ALIMCO), established by Ministry of Social Justice and Empowerment, Government of India, provides assistive aids to the disabled and elderly. ALIMCO produces 355 different kinds of assistive aids for orthopedically, visually, and hearing impaired people and partners in various government schemes like Rashtriya Vayoshri Yojana to provide such aids to target beneficiaries generally poor people (www.alimco.in). Manufactures like Dhingra Surgicals, Navchetan Orthopedic Appliances, Surgical electronics, Narwal Orthopedic and Rehabilitation Aids, Surgico-Furn (India) Ltd., SAGE (Everest engineers) and organisations like Bhagwan Mahaveer Viklang Sahayata Samiti are also working on developing mobility aids, prosthesis, tricycles, wheelchairs, commode pot chairs, cervical aids, abdominal supports, various hand and leg supports, orthopedic shoes, calipers, etc, to help elderly in living their life independently and participate actively in social life. A majority of other kinds of aids, viz. communication aids, dressing aids, self-care aids, recreational aids, are not manufactured in India but can be purchased from e-commerce sites although at a very high price. The Department of Science and Technology, Government of India has documented addresses of some manufacturers and e-commerce sites on the Web portal www.oldagesolutions.org created under the Technology Initiatives for Disabled and Elderly (TIDE) scheme of the Science for Equity, Empowerment, and Development (SEED) Division.

Some other ideas/innovations about ATs by grassroots innovators and students have been recognized by the National Innovation Foundation—India which can prove beneficial to the elderly. Some such ideas/innovations include a chair with shower system for elderly to take bath independently by K P Gopalakrishnan, a walker with height adjustable front leg to climb stairs by Shalini Kumari, a walking stick with features like counting of steps, medicine reminder, locator, emergency alarm, fall detector, and automatic torch by Siddhant Khanna, shoes with a negative heel to alleviate knee pain among elderly by S K Pasha, and modified wheelchair that can be converted into crutches by S Ramakishore, Sanjay Srinivas, Tamil Selvan, among others [31].

Initiatives have also been taken by some researchers to develop assistive aids suitable for the Indian elderly. Megalingam et al. have proposed a system HOPE with sensors to monitor heart rate, body temperature, tilt and fall and send the data to caregiver in case of emergency [32]. Mohan Kumar et al. have developed multipurpose wheelchair, which also assists in defecation, cleaning, and changing of clothes. In the wheelchair, a provision of adjustable armrest, backrest, and leg rest has also been made to provide comfort to users while resting [33]. A low-cost version of the wheelchair, which can also assist users in standing up, has been developed by Srinivasan, IIT Madras [34]. An ergonomic wheelchair with features like back reclination and standing mechanism has also been designed by Oram [35]. A device for managing urinary incontinence in old age has been developed by Ramesh et al. [36]. Bed rail for elderly, which can assist them in getting in and out from bed, has been developed at IIT Mumbai [37]. Kadam and Diwate evaluated a technical aid, which assists users in getting in and out of the bus [38]. Thakur et al. have designed a noninvasive technique for monitoring of human heart functioning through speech analysis by which patients can monitor their heart functioning themselves [39]. A tablet-based system to check the well-being of the elderly has been designed and assessed by Ray et al. [40]. Sarkar and Das conceptualized modularity in powered wheelchair for elderly with mobility impairment [41].

46.3.4 Challenges in the Areas of Assistive Technologies in India

In order to make assistive technologies accessible and adoptable for the elderly, some of the key challenges have to be resolved. Lack of awareness among users regarding available aids and their utility, source of availability, cost, operating cost, support services, etc, should be addressed. Creating awareness among stakeholders (designers, architect, technologists and other specialists, industry and service providers, etc.) for the needs and constraints of the user is also required [30]. The anthropometric measurements of Indian elderly have not been recorded till date; therefore, designers have to rely on data collected by different researchers in their study areas [42–45]. But whether it can be directly manipulated for the whole country or used in association with anthropometric database of Indian adults should be carefully analyzed. Though geriatric anthropometric database of different countries is available [46–50], it differs from the anthropometric measurements of Indian elderly.

The designers should also assess local demands, sociocultural environment, gender and financial constraints, and attitude of the users [51]. Understanding user's perspective before developing any product is essential for its adaptability [52]. Lack of trained professional to guide and instruct users on the use of AT is another challenging area. Adequately trained professional like occupational therapist (OT) and physical therapist (PT) can assess the needs of users and train them in using appropriate technology and services [12]. Market assessment to resolve supply barriers like low production and financial constraints is also required [53]. Legislation and government initiatives to support research and development in the AT and their integration with health and social services will promote the development of innovative aids and increase its utilization [12].

46.4 Future Scope in the Field

Various kinds of mobility, vision, and hearing aids for elderly are being developed in India, but there are other areas like aids for self-care, sit–stand transfer, recreational activities which needs attention of researchers. Sit–stand transfer is one of the major problematic areas as the elderly face difficulty in getting up from chairs, sofas, toilet seat, bed, etc. Currently, available walkers and walking sticks can only be used for mobility and do not serve the purpose of sit–stand adequately. Another area, which needs immediate research intervention, is an aid for sit–stand transfer for the elderly that can be used in Indian type of toilet, the most common type of toilet in rural India. Other activities such as wearing socks, shoes, combing can also cause difficulty to the elderly. Gandhi has also suggested having grab bars, tap turners, rail support, high wooden stool, low towel stand in bathrooms for the elderly [54]. Similarly, in Indian kitchens, prolong standing for cooking, dishwashing, jar opening, gas stove knob turning, using grater are other activities, which need intervention in form of assistive aids for the elderly.

Though some innovative aids have been developed in recent years like walker for climbing stairs, multipurpose wheelchair, wheelchair that can be converted into crutches, bed rail, etc, elderly are not getting proper benefit of these aids because of availability issues and also that the awareness regarding these aids is quite low among the elderly. Society's perception toward assistive aids is another challenging area. Therefore, designers should work for developing aids that are more appealing to the users and fulfill their needs. Incorporation of ergonomics features and consideration of sociocultural, gender, and financial constraints are important factors in aid design. Selection of lightweight and durable material is essential for the aids.

Lack of interest and initiatives by industries to convert ideas and research into prototype is hampering the growth of this sector. So there should be an effort by the government and media, that awareness and favorable attitude toward these aids among elderly are created so that they can do their daily activities with ease and comfort. The entrepreneurs should also come forward and work in the area of developing prototypes and bring the efforts of researchers for the benefits of elderly.

46.5 Conclusion

Assistive technologies facilitate elderly in doing their day-to-day work with ease and comfort. These aids encourage them to participate and maintain their social life. Variety of assistive aids such as mobility aids, hearing aids, spectacles, prosthesis is being used by elderly in India. But there are other kinds of aids like communication aids, dressing aids, self-care aids which help elderly in doing their activities of daily living independently. Majority of such aids are not manufactured in India and can be availed only at a high cost.

Except many of the commonly available aids, the elderly are mostly ignorant about the availability of others, even if they are aware, where from and how to procure them, becomes an issue. Hence, the factors of awareness, availability, and accessibility become important in context of the Indian elderly, as the case may be in many other countries. The country has a large middle class, and hence, in addition to the above three, affordability is another important factor that needs consideration.

Given the large disparity in income, difference in culture, racial variation, areas of habitation, living habits, etc, in the country, incremental variations to suit regional needs may have to be incorporated in ATs. Hence, effort may also be made to develop, to the best extent possible, culture-specific, low-cost aids so that these can then be made available to the people and can be readily used by them. For a big country like India, from the review, it is also apparent that the amount of research, which should have been undertaken in this field, is somehow probably not happening. There is need of research to incorporate ergonomic design features in available assistive devices to make it more comfortable for the users. The designers should also work on making the assistive aids more appealing to the elderly. Most of the researches on assistive technologies in India are focused on few areas like bathing activity, toileting, mobility, and security systems at home. Though these are the most important activities of daily life, other areas like assistive aids for dressing, kitchen work, and communication are often neglected. There are regional and cultural variations in dressing styles across the country. Therefore, dressing aids suitable to the needs of Indian elderly should be developed. Similarly, kitchen gadgets appropriate for Indian cooking styles and communication aids should be designed for the comfort of elderly. It is therefore very urgent and important to undertake more research in the field of ATs and especially for the elderly so that a plurality of affordable choices is available to the people to make an informed decision.

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Chapter 47
Association Between Adopted Posture and Perceived Vibrational Discomfort Among Stone Polishing Workers

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Abstract This study examined the work-related discomfort among the workers engaged in stone polishing activities, from Guwahati, India. Data was collected through questionnaire-based interview and direct observation of the stone polishing process. The working postures of the stone polishing workers were evaluated through direct observation of the workers at their workstation using the Rapid Entire Body Assessment (REBA) method. The vibration level was measured using hand-arm vibration meter, VM31 in each of the direction (*X*, *Y*, and *Z*), and measurement techniques were followed as described in European Occupational Health Directive 2002/44/EC and ISO 5349-1. A high proportion of workers had a neck (48.9%), shoulder (51.1%), wrist (84.4%), elbow (83%), feet (53.3%), and knee (31.1%). The final grand score was 9 (floor), 7 (wall), and 10 (staircase). It indicates that the overall postural load was of very high risk, and changes and implantation were required very soon. The measured eight-hour energy-equivalent frequency-weighted acceleration magnitude [A(8)] for each of the participant vibration value was also beyond the exposure action value (2.5 m/s^2) and exposure limit (5 m/s^2).) There was significant association between the perceived discomfort of individual body parts and measured resultant of vibration at the wrist of the different location. There was also a significant correlation between discomfort of overall body parts of the stone polishing workers and measured resultant of vibration at the handle of different location (floor, wall-base, and staircase). Therefore, this study tried to examine whether there is an association between working posture and the overall discomfort of the polishing workers while pursuing different types of polishing activities.

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47.1 Introduction

Decorative stones like marble are attached on the floor, walls, staircase to adorn the beauty of floor, tabletops, etc. These stones gradually lose their luster, and hence, polishing technique is used to provide luster to the stone. Among various hazardous activities in the construction sector, stone polishing is one where the use of handheld vibrating tool is a regular part of their deeds. Stone polishing workers use handheld polishing machine to control the surface finish and quality of the intended surface of the stone/mosaic. Polishing workers operate the polishing tool manually in either squatting or sitting position for prolonged duration, and it involves drudgery while operating. Adaptation of awkward working posture, repetitive forceful movement, prolonged work duration, and improper working tool are some of the ergonomic stressors associated with the stone polishing work. The operators of the stone polishing machine are generally exposed to extreme vibration at the grip, which has been reported as the salient drawback of the existing polishing machines in the market. The vibration from the handle of the polishing machine gets transmitted to the hands, arms, and shoulders of the operator. It causes discomfort to the operator and results in early fatigue. When such fatigue prevails over a period of months and years, they may cause physical, physiological, and musculoskeletal disorders [1]. Moreover, sustained sitting or standing awkward posture for long duration increases the demand on the muscles, ligaments, and other soft tissues of the musculoskeletal system. These cause overall discomfort and pain in the back, neck, and shoulders of the workers [2, 3]. Earlier reported studies highlighted that the use of vibrating hand tools is one of the main work-related cause of disorders at wrist, elbow, and neck [4–6]. A few kinds of literatures also stated that musculoskeletal disorders of the neck and upper limbs were reported by workers involved in awkward postures, repetitive movements, and high force [7, 8]. Various research works have been carried out in Indian scenario to assess ergonomic stressors and to report on the occurrence of WMSDs associated with different formal and informal occupational setups to propose or implement ergonomic design interventions [9–11]. As far as stone polishing workers are concerned, there had been scantly literature which deals with the ergonomic risk factors, thereby occupational health issues and their corresponding remedial measures including ergonomic design interventions. Vibration transmission in the human body is influenced by various work-related factors such as posture, pushing force, and gripping [12]. Moreover, there is rarely any study highlighting health implications of the polishing workers due to use of handheld polishing machines with diverse types of adopted posture. Therefore, this study tried to examine whether there is an association between corresponding working posture and overall discomfort among the polishing workers while pursuing different types of polishing activities on different surfaces at the construction site (Fig. 47.1).

Fig. 47.1 Awkward postures adopted by the operators during polishing activities at different surfaces

47.2 Method

47.2.1 Participants

The study sample consisted of 45 adult male stone polishing workers across Guwahati city, Assam. The participants were selected following purposive sampling from the different places of the city, namely Lokhra, Ambari Fatasil, Ganesguri, and Amingaon.

47.2.2 Data Collection

The subjects were informed about the purpose of the study, the experimental procedure, and their role in the research in vivid details. Consent for participation in the study was obtained from each of the participant (polishing worker) before involving in the study, and the entire data collection was performed in accordance with the Helsinki protocol [13]. Since the workers were not well-versed in English, the questions were explained in their vernacular language and data was filled in by the interviewer.

Data related to demographic characteristics (age, gender, height, weight, etc.), job experience (years), daily working hours, working condition, job satisfaction, perceived vibrational discomfort, etc., was collected through questionnaire-based interview and direct observation of the polishing process at the construction sites. The questionnaire was evaluated through a pilot study with a sample of 12 participants, and corrections of the wording of some question were made based on the feedback from the pilot study. The reliability of the questionnaire was found to be good (Cronbach's alpha = 0.8).

The standardized Nordic questionnaire was used to investigate the prevalence of the symptoms of musculoskeletal ailments and identify the suffered body parts [14]. The procedure involved showing a body map to volunteers and recording the responses to various queries in the questionnaire. The workers were asked to indicate if they had experienced any ache, discomfort in the last 12 months and in the last 7 days for the body areas including shoulders, neck, upper back, elbows, low back, wrists/hand, knee, and ankles/feet. The severity of the symptoms was rated in the different areas using a scale of 1–5.

Photography and videography of the operators during their stone polishing activities were recorded for detailed understanding of the polishing process, and the postures adopted by the operators' postural load of the stone polishing workers were evaluated through direct observation of the workers at the work site and from the recorded photographs/videos using the Rapid Entire Body Assessment (REBA) [15] for all the locations (floor, wall-base, and staircase) under study.

During polishing activity, the magnitude of transmitted vibration (from the handle of polishing machine) at the wrist of right hand of the operator was measured (Fig. 47.2) using hand-arm vibration meter (Make: Manfred Weber, Model: VM31-HA) following the measurement techniques as described in European Occupational Health Directive 2002/44/EC and ISO 5349-1. The magnitude (acceleration) of the hand-transmitted vibration for all the three axes (X, Y, and Z) and their vector sum (as mentioned in EN ISO 5349: 2001) were recorded for 30 s. (after 1 min. of polishing activity) during performing the polishing at floor, wall-base, and staircase.

47.2.3 Statistical Analysis

Statistical analysis was done by using IBM SPSS software (version 20.0). A descriptive statistical analysis was used to represent the personal data, distribution of reported pain, perceived vibration discomfort, measured vibration values, and REBA scores of individual body segments as well as overall REBA score. Spearman's correlation was performed to contemplate the association between different adopted posture and perceived discomfort.

Fig. 47.2 Hand-arm vibration meter connected with the triaxial accelerometer (left image) and triaxial accelerometer on the wrist of the operator during use of polishing machine (right image)

47.3 Result

47.3.1 Characteristics of Participants

Demographic profile of the workers reported that the mean age of the workers was 25.64 years and it ranged from 17–34 years. Among the participants/volunteers, 53.3% were illiterate while remaining 46.7% had of primary education. All the participants were male, and their age ranged 17–34 years. Detailed demographic characteristics and job profile have been mentioned in Table 47.1.

47.3.2 Discomforts in Various Parts of the Body

The occurrence of discomforts/pain in various body parts of the participants and thereby disruption of their regular activities at workplace or outside the workplace are shown in Fig. 47.3. The prevalence of pain in various body parts of the volunteers was high in general. The percentages of the participants suffered from discomfort at neck, shoulder, wrist, elbow, ankle/feet, and knee during the last 12 months were 51, 52, 70, 60, 57.7, and 46.6%, respectively. The pain affected their normal activities both at work and outside their work. During the last 12 months, the numbers of participants whose normal activities were disrupted due to discomfort at neck, shoulder, wrist, elbow, ankle/feet, and knee were 75.6, 63.8, 67, 51, 64, and 43.5%, respectively.

47.3.3 Perceived Discomfort and Magnitude of Hand-Transmitted Vibration

During stone polishing activities, the vibrational energy is transmitted from the handle of the equipment to the hand of the operators as they firmly hold the

Table 47.1 Demographic characteristics and job profile of the participants (n = 45)

Characteristics	Mean (±SD)
Age	25.64(5.4)
Height	156.16 (6.6)
Weight	49.87(4.7)
Work experience	3.42 (1.6)
Working hours per day	4.64 (0.9)
Working days per week	4.96 (0.2)
Number of breaks in a day	3.16 (1.1)
Duration of total breaks in a day	2.20 (1.2)

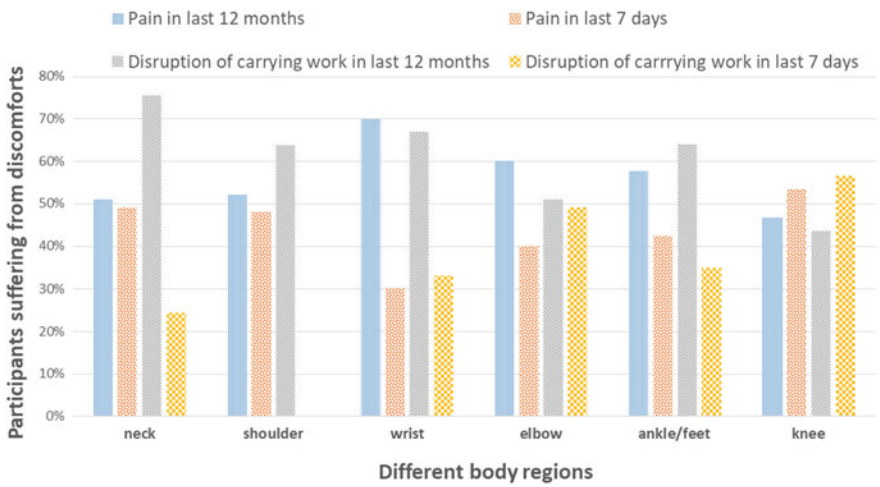

Fig. 47.3 Observations from the responses against the standardized Nordic questionnaire as reported by the participants

machine with both the hands. Majority of the participants of the present investigation reported extreme vibration discomfort irrespective of their working location (floor, wall, and staircase). Initially, the discomfort due to vibration is felt more on the hands, and then it gradually decreases as they continue to operate the machine. The participants reported when they take a few days leave from their work and return to their working place, the vibration discomfort is felt more. In that particular case, they need to take more frequent breaks to overcome the discomfort caused by the vibrating polishing machine. The arm/elbow of the operators is generally supported on their knees to bear the load/weight (2.8–4.0 kg) of the polishing machine. The responses were collected from the participants regarding their perception related to overall vibrational discomfort (on a 5-point visual analogue scale starting from 'very less discomfort' and ending at 'extreme discomfort') during polishing activities. It was found that about 71.2% of the participants reported their level of perceived vibrational discomfort as extreme or very high, 20% reported as high, 4.4% of the participants felt it moderate, and 4.4% of the workers felt the vibrational discomfort as low while operating the stone polishing machine. It was also noticed that 95.6% of the participants had the numbness and tingling sensation on their palms and fingers. About 46.7% of the workers had high muscle and joint pain in their hands and arms, and 55.6% of the participants had visited physician for pain in the hands and arms during last 12 months. The data (Table 47.2) collected using hand-arm vibration meter revealed that the eight-hour energy-equivalent frequency-weighted acceleration magnitude [A(8)] for each of the participant was more than the recommended daily average vibrational exposure (action value = 2.5 m/s^2 and exposure limit = 5 m/s^2).

Table 47.2 Magnitude of vibration (vector sum and daily vibration exposure) at the wrist of stone polishing machine

Participants	Floor		Wall-base		Staircase	
	Vector sum (m/s^2)	Daily vibration exposure A (8)(m/s^2)	Vector sum (m/s^2)	Daily vibration exposure A (8)(m/s^2)	Vector sum (m/s^2)	Daily vibration exposure A (8)(m/s^2)
1	20.06	3.9	11.14	2.93	45.05	3.15
2	42.64	3.12	5.26	2.47	21.7	3.9
3	42.64	3.52	4.06	2.87	34.44	3.26
4	10.28	2.2	16.04	2.65	35.05	3.42
5	4.84	3.53	9.41	2.35	11.81	2.98
6	14.08	3.53	10.38	2.79	36.05	3.15
7	12.37	2.45	8.8	2.2	10.12	2.45
8	49.34	3.67	16.44	2.67	16.04	2.65
9	10.82	2.48	15.07	2.97	25.2	4.1
10	8.9	3.34	11.51	2.79	6.24	2.45
11	3.09	2.2	42.64	3.12	11.7	3.9
12	1.86	2.87	13.48	2.84	4.95	2.55
13	8.5	2.35	9.95	2.55	9.08	2.45
14	8.8	2.2	6.24	2.45	7.31	2.21
15	11.37	2.45	13.48	2.84	16.44	2.85

47.3.4 Posture Analysis

The REBA score (score A, score B, and final score) of stone polishing worker while carrying out polishing work at different locations (floor, wall-base, and staircase) is shown in Table 47.3. During polishing work, both the upper arm(s) of the operators remain abducted and flexed between 20° and 45°. In present study, the score of upper arm was found between 2 and 3. The lower arm score was found to be 3 as the participants were working across midline of the body with elbow flexion less than 60° or more than 100°. The wrists of participants were in extension (sagittal plane) of up to 15°, and thus, the REBA score was 3. The neck score and trunk score were 2 and 3 as the participants' necks and trunks were in more than 20° flexion to the front during performing the polishing. The leg score was generally found to be 2. The REBA grand scores were 9 (floor), 7 (wall-base), and 10 (staircase) for different locations of polishing. Overall postural load was of very high risk and immediate implementation of intervention strategies to correct the awkward posture soon.

Table 47.3 REBA scoring for stone polishing worker during polishing activities at different locations (n = 45)

REBA Score	Floor polishing			Wall-base polishing			Staircase polishing		
	Score A	Score B	Final score n (%)	Score A	Score B	Final score n (%)	Score A	Score B	Final score n (%)
1	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–
5	5(3.92)	–	–	–	3(6.7)	7(15.6)	1(2.3)	–	–
6	7(15.6)	2(4.5)	–	9(20)	8(17.8)	13(28.9)	1(2.3)	–	–
7	8(17.8)	2(4.5)	–	2(4.5)	20(44.5)	5(11.2)	–	3(6.7)	–
8	23(51.2)	15(33.4)	–	31(68.9)	6(13.4)	10(22.3)	3(6.7)	5(11.2)	–
9	2(4.5)	14(31.2)	25(55.6)	–	8(17.8)	5(11.2)	3(6.7)	2(4.5)	2(4.5)
10	–	12(26.7)	13(28.9)	3(6.7)	–	3(6.7)	19(42.3)	8(17.8)	8(17.8)
11	–	–	7(15.6)	–	–	2(4.5)	18(40)	27(60)	35(77.8)
Mean (SD)	7.2(5.2)	8.7(4.4)	9.6(6.0)	7.7(7.3)	7.2(4.5)	7.2(3.5)	10.0(5.5)	10.2(6.1)	10.7(8.4)

47.3.5 Association Between Different Adopted Posture and Vibration Discomfort

Correlation between REBA score of individual body parts with the level of perceived discomfort at individual body segments (from Nordic questionnaire) was assessed (Table 47.4). There was no significant correlation between the aforesaid two data sets.

Perceived overall discomforts (irrespective of individual body segments) were rated by the participants in the questionnaire. The REBA grand score was high for the participants due to their adopted awkward posture, and the perceived overall discomfort (irrespective of individual body segments) during working was also high but there was no significant correlation (Table 47.5).

Insignificant correlation between REBA score of individual body part and its level of perceived discomfort (from Nordic questionnaire) as well as insignificant correlation between REBA grand score and overall all perceived discomfort, indicated that the root cause of discomforts at individual body segments or overall body discomforts is not the awkward adopted posture during polishing activities. The source of discomfort might be associated with vibration generated and transmitted to human body from the polishing machine.

It was observed that significant correlations were present between perceived discomfort of individual body parts and measured intensity (vector sum) of the vibration at right wrist during performing polishing activities in various locations like floor, wall-base, and staircase (Table 47.6.).

Table 47.4 Correlation of individual REBA score and perceived discomfort of individual body parts

Perceived discomfort of body parts	REBA individual score (floor) (NS)	REBA individual score (wall) (NS)	REBA individual (floor) (NS)
Neck	0.027	0.012	0.027
Trunk	0.061	0.076	0.043
Upper arm	0.018	0.053	0.047
Lower arm	0.033	0.074	0.092
Wrist	0.072	0.086	0.076
Feet	0.086	0.052	0.058

Table 47.5 Correlation between REBA grand score and overall perceived discomfort

		Perceived overall discomfort (NS)
Spearman's rho	REBA grand score (staircase)	0.073
	REBA grand score (wall-base)	0.167
	REBA grand score (floor)	0.044

*Correlation is non-significant (NS) at the 0.05 level (two-tailed)

Table 47.6 Correlation between perceived discomfort of individual body segments and measured vibration intensity at wrist during polishing activities at different locations

Different location–Vector sum of vibration at wrist	Neck	Shoulder	Wrist	Elbow	Feet	Knee
Wall-base	0.748**	0.748**	0.748**	0.748**	0.748**	0.748**
Floor	0.758*	0.758*	0.758*	0.758*	0.758*	0.758*
Staircase	0.852**	0.852**	0.852**	0.852**	0.852**	0.852**

*Correlation is significant at the 0.05 level (two-tailed)
**Correlation is significant at the 0.01 level (two-tailed)

Table 47.7 Correlation between perceived overall body discomfort and measured vibration intensity at right wrist

	Measured intensity of vibration (Staircase)	Measured intensity of vibration (Floor)	Measured intensity of vibration (wall)
Perceived discomfort of overall body parts	0.703*	0.705*	0.810**

*Correlation is significant at the 0.05 level (two-tailed)
**Correlation is significant at the 0.01 level (two-tailed)

Similarly, there was significant correlation found between perceived overall discomfort of the participants and measured intensity of vibration (vector sum) at right wrist during carrying out polishing at different locations like floor, staircase, and wall-base (Table 47.7).

Correlations between measured vibrational intensity (vector sum) and perceived discomfort at individual body segments or overall body were found significant. This implies that the exposure to predominantly high level of vibration intensity during polishing activities might be responsible for the perceived discomforts by the participants. There is a need of design interventions of the stone polishing machine to ameliorate the exposure to vibration to enhance safety for the well-being of the polishing workers.

47.4 Discussion

The current study found that occurrence of pain/discomfort among the stone polishing workers was prevalent. A high proportion of workers reported discomforts at neck (48.9%), shoulder (51.1%), wrist (84.4%), elbow (83%), feet (53.3%), and knee (31.1%). To confirm the ergonomic risk related with current working postures adopted by the workers, REBA method was carried out. The analysis showed that the REBA grand score values were high (floor = 9, wall-base 7, staircase = 10) in all cases of polishing activities, which indicated high risk and requirement of investigation and changes of the working tool/equipment, introduction of proper work–rest cycle, etc., at the earliest. The work of highly monotonous in nature and occurring for a long duration might results in pain and discomfort [16]. This is also applicable in case of stone polishing activities where a sufficient association was seen in between longer polishing hours and high chance of pain in upper arm, lower arm, and lower back of the workers. Continuation of work for long duration and repetitive work without proper break incline to exaggerate the musculoskeletal symptoms whereas with proper break in between every working hour can significantly reduce the pain risk [17]. In present study, it was also found that workers having more breaks in between working hours had less pain in lower back, upper arms, and lower arms.

Perceived vibration discomfort while operating the polishing machine is another factor that has significantly affected the prevalence of body parts' discomforts mainly in wrist, elbow, and shoulder of the workers. The measured vibration intensity at the right wrist of the operator was found to beyond the exposure action value (2.5 m/s^2) and exposure limit (5 m/s^2). The studies had mentioned that more working experience of performing a work could be an important factor in diminishing the risk of work-related pain in case of wrist pain [18]. In case of the polishing workers, the workers reported that during the initial days of their stone polishing work, pain was more but greater practice lead to reduction of pain in wrist, elbow, neck, and shoulder. A greater practice can be effective in fine movements without hurting their wrist inducing in wrist pain and increase in output [16].

During the polishing work, various awkward postures like forward bending of the trunk, forward and side bending of the neck, chin on the knee, forward side bending, hands supported on the knee along with frequent forceful arm movements were noticed among the stone polishing workers irrespective of working location (floor, wall, and staircase). The present polishing activity use similar kind of attributes, so the response for pain was same for all the location (floor, wall, and staircase). Although the REBA score for individual body was high and the perceived discomfort for individual body parts of the workers was high, there was no significant correlation between them. Even there was no correlation between REBA grand score and perceived discomfort of overall body parts of the workers. But then there was significant correlation between perceived discomfort and measured intensity of vibration at the handle. It clearly indicates that working posture was not causing problem for the workers. The main reason for discomfort during their working hours was the extensive vibration transmitted to the hand-arm system of the polishing workers. As reported by the workers, there was tingling sensation felt by them while performing stone polishing activities. All these above-mentioned factors can be accepted broadly as a sign of improper workstation design and improper working equipment [18]. Hence, this study recommends and supports the need for design intervention of proper working equipment, in the present scene would be for marble polishing activities. Some ergonomic design intervention might significantly help in reduction the vibration exposure, repetitive movement, force requirement for the work, and overcome with the pain-related issues.

47.5 Conclusion

Therefore, in this study, it could be concluded that stone polishing workers work with improper working equipment/tool and uncomfortable postures with the progressive risk of MSDs primarily affecting the different regions of body parts, as found from the observation and analyses of the results. The factors mainly associated with their discomfort while performing polishing activities were the nature of job task that marks the repetitive and tedious work, long duration of working hours, awkward postures, and extreme exposure to vibration. Therefore, there is need of ergonomic intervention of tools/equipment in terms of reduction of vibration exposure, proper anthropometric compatibility to ameliorate the working condition of the stone polishing of the workers.

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Chapter 48
Dynamic Behavior Analysis of Grass Trimmer Using Finite Element Method

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Abstract Dynamic behavior analysis of structural components is one of the important tasks in the design process of any mechanical system. Nowadays research personnel are intended to carry out research in this area to increase the efficiency and functionality of mechanical systems. The vibrational characteristic is very important in many dynamic machine components design and analysis. Among these machine structures, grass trimmer is one of the most common machines that exposed to the dynamic and static forces, coming from the engine and rotating blade. Prolonged exposure of grass trimmer leads to hand-arm vibration (HAV) syndrome to the operator. In this research, the dynamic behavior analysis of grass trimmer is performed by taking the dimension of the existing grass trimmer available with workers at NIT Rourkela. In totality, nine numbers of models are developed by changing the handle positions from cutter head as 1000, 1100, and 1200 mm at an angle of 90°, 60°, and 45°, alternatively. Harmonic analysis is carried out to evaluate the sustainable, dynamic behavior of the grass trimmer by estimating the natural frequencies and mode shapes. Based on the harmonic analysis, it is observed that model with 1100 mm @ 60° handle position from cutter head is the optimum position because at this point vibration induced is least as compared with other models. After finding optimum handle position, a new handle design is proposed with a rubber mount and a thin cover of thickness 2.5 mm attached in between the shaft and handle. The analysis is performed on new design and found that the root mean square (RMS) value of the average acceleration at handle position is reduced appreciably as compared with the existing grass trimmer.

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48.1 Introduction

The grass trimmers are commonly used in industries and agriculture for cutting the grass in India. The Indian farmers while cutting grass in the fields have to put lots of effort for grass trimmer operation. The major problem in grass trimmers is handle vibration at the handle position in both agriculture and industrial grass trimmer. The continuous usage of grass trimmer exposes the user to the risk of HAV syndrome. A common source of vibration in grass trimmer is depended upon handle material, engine speed, and nylon thread length.

Developed a human arm of five DOF (degrees of freedom) bio-mechanical devices with the help of an energy flow meter to identify the modal parameters [1]. Here, the maximum hand-arm excited vibration is mostly affected to forearms and elbow, and it ranges from 20 to 100 Hz. [2] examined the effect of handle size (30, 40, and 50 mm diameters) and hand force (combination of push force (25, 50, 75 N) and grip force (10, 30, 50 N)) exerted on vibrating machine (random vibration along *Z*-axis) on the mechanical impedance through laboratory. The coupling force and contact force can be associated with the driving force at above/below frequency range 250 Hz. [3] evaluated the frequency-dependent rubber damping characteristic and mount stiffness by using measured frequency responses from the impact test are examined experimentally. [4] considered various parameters such as handle position, sway angle, cutting thread, and engine speed to optimum design of grass trimmer machine is analyzed via orthogonal array. The experimental result at 170 mm length of thread (nylon) runs the engine at 3000 ± 4000 RPM, 45° of sway angle combination results give minimum vibration at the handle position (2.45 m/s^2). [5] used a D-shaped handle at high speed, resultant in high-level vibration among the workers. This research proposes a new handle design to the grass trimmer. The new handle is compared with old handle and finds lowest hand-arm vibration. Here, the handle parameters (such as handles length, angles, and material of the cap) are optimized with the Taguchi quality tool. [6] investigated grass trimmer parameter such as engine speed (3000 ± 400, 4000 ± 400, 5000 ± 400), nylon thread length (100, 150, and 200 mm), handle material (ABS, wood, and steel) for analysis. From the analysis, it was found that 100 mm nylon cutting thread, 3000 ± 400 rpm engine speed, and ABS handle material give less hand-arm vibration. Designed and developed a suspended handle with a rubber mount placed in between the base plates to reduce HAV in grass trimmer [7]. Then the handle vibration is reduced to 2.69 m/s^2, when compared with the commercial handle (11.30 m/s^2). [8, 9] investigated the vibration of electrical grass trimmer by attaching tuned vibration absorber at shaft position. The vibration of grass trimmer is analyzed by using an imposing node technique and found that reduction in weighted RMS acceleration at loop handle 71% and a rear handle 72% in comparison of commercial grass trimmer.

In this work, a new grass trimmer is modeled and analysis concerning the commercial grass trimmer. To check the dynamic behavior of the grass trimmer, modal analysis is carried out to determine the natural frequencies and mode shape of the grass trimmer using ANSYS software. To check the robustness of the grass trimmer, harmonic response analysis is used to evaluate the handle vibration of the grass trimmer and determine the optimum parameter of the grass trimmer. The importance of this work is to protect the worker from the musculoskeletal disorder. In this work, a new handle is designed with a rubber mount in between the base plate and cap of the handle to reduce the handle vibration at an optimum level. The following assumptions are considered for new handle design by changing the different materials of the handle, handle position, and handle angle.

48.2 Design of Grass Trimmer

48.2.1 Design Considerations of Grass Trimmer

In general, most of the tools are not ergonomically design may lead to injury in the operator's hand. It is needed to design a tool in such a way that, it will fulfill the ergonomic criteria. Nowadays, in the market most of the grass trimmers are not ergonomically designed, which causes an injury to the operator's hand. A new grass trimmer is designed ergonomically to reduce the HAV syndrome for the users are explained in the following sections.

48.2.2 Modeling of Grass Trimmer

The parts of the grass trimmer are designed using CATIA software. Grass trimmer dimensions are taken from the commercial grass trimmers used in NIT Rourkela. Here, two types of grass trimmers have been designed based on the ergonomic point of view as well as vibration reduction scheme.

48.2.2.1 The Ergonomic Design of Existing Grass Trimmer

First type of grass trimmer is designed ergonomically based on the dimensions taken from the commercially used grass trimmer in NIT Rourkela. For designing the dimensions of the commercial grass trimmer model was shown in Table 48.1. Here nine models are designed in CATIA software by changing the man's handle position from the cutter head and handle's angle of the grass trimmer. Here, the grass trimmer models are designed and developed by varying the handle position (1000, 1100, and 1200 mm) and handle angle (45°, 60°, and 90°). Total nine models are designed and are shown in Fig. 48.1.

Table 48.1 Dimension of the new grass trimmer with cover's shaft ABS

Parts of grass trimmer	Length (mm)	External diameter (mm)	Internal diameter (mm)	Thickness (mm)
Drive shaft	1600	35	32.5	2.5
Cover of the drive shaft	1600	32.5	30	2.5
Base pipe of the handle	400	30	20	10
The shaft of the handle	180	20	17.5	2.5
Rubber mount of the handle	30	30	20	2.5
Cap of the handle	100	40	35	5-10

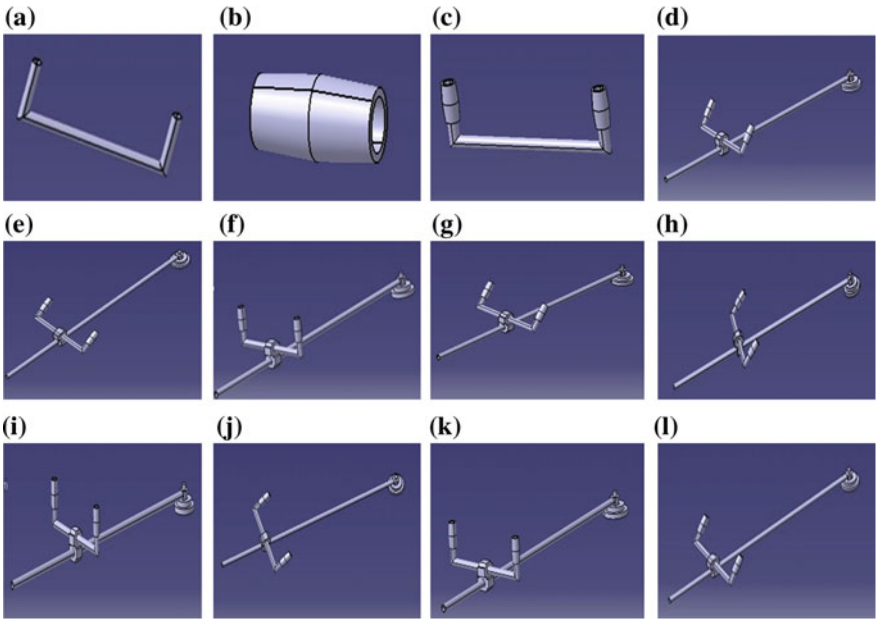

Fig. 48.1 **a** Handle pipe, **b** Cap of the handle, **c** Assembly of handle, **d** Model no.1, **e** Model no.2, **f** Model no.3, **g** Model no.4, **h** Model no.5, **i** Model no.6, **j** Model no.7, **k** Model no.8, **l** Model no.9

48.2.2.2 Ergonomically Design of 2nd Type of Grass Trimmer

The handle of the grass trimmer is designed ergonomically according to [3]. During handle design rubber mount is inserted between the base of the rod and cap of the handle. Rubber mount was made up of ABS and was used as a good shock absorber. Optimizes different parameter of grass cutter handle with the commercial

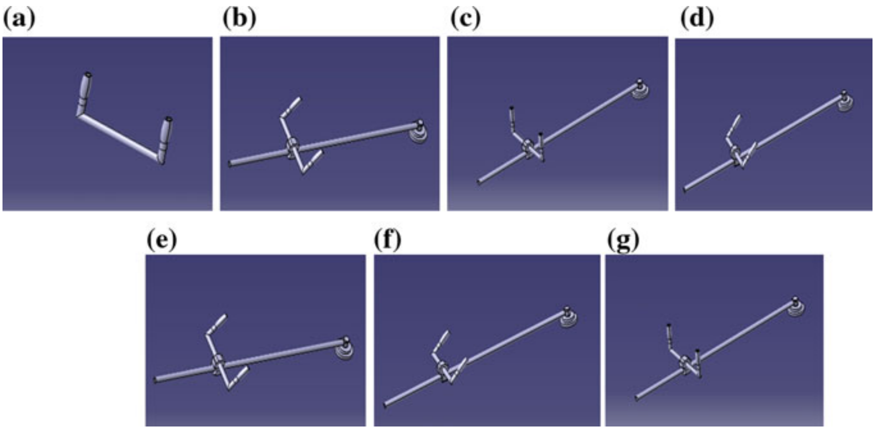

Fig. 48.2 **a** Assembly of handle, **b** Model no.10, **c** Model no.11, **d** Model no.12, **e** Model no.13, **f** Model no.14, **g** Model no.15

grass trimmer [4]. Here ABS is inserted in between the base plate and handle then it attenuates the vibration level 76% compare with commercial handle. According to this concept grass trimmer handle is to be designed with a rubber mount between the base pipe and cap of the handle. Here six models of grass trimmer are made to check the optimum level of grass trimmer. Here the models (10th, 11th, and 12th) are designed for 1100 mm handle position from cutter head with rubber mount handle and 2.5 mm thickness rubber on the shaft by varying handle angle (45°, 60°, and 90°). Similarly, the remaining three models (13th, 14th, and 15th models) are designed in the same phenomena by adding rubber mount handle and 2.5 mm thickness cover's ABS on the shaft. CATIA modal of grass trimmer with rubber mount and cover on the shaft which made by rubber/ABS are shown in Fig. 48.2 respectively.

48.3 Finite Element Analysis of a Grass Trimmer

The FE analysis of grass trimmer is analyzed using ANSYS software. The dynamic analysis of the grass trimmer is done with the modal analysis and harmonic analysis. Modal analysis is carried out to determine the natural frequency and mode shape of the different models of the grass trimmer in ANSYS workbench, by taking the dimension of existing grass trimmer with ergonomic design considerations. From this model by changing the three handle angle (90°, 60°, 45°) and three handle position from cutter head (1000, 1100, 1200 mm) made nine models of the grass trimmer are analyzed. Analysis is carried out on the existing as well as newly designed grass trimmer. In this analysis, assume that model was fixed of grass trimmer at the end of the shaft and assume that it was cantilever beam. Motor

Table 48.2 Material properties of the grass trimmer

Material	Steel iron	ABS	Rubber	Cast	Wood
Density(kg/m3)	7750	1052	1520	7200	0.9
Young modules (GPA)	1930	2	0.05	110	3.6
Bulk modules(GPA)	169	2.22	0.416	83.33	6
Shear modules(GPA)	76.31	0.74	0.016	42.96	1.28
Poisson's ratio	0.31	0.35	0.48	0.28	0.4

weight was considered 3 N and unbalance force was considered as constant 8 N. In this analysis, different materials were taken and their properties are shown in Table 48.2.

48.3.1 Modal Analysis of Existing Grass Trimmer

First modal analysis was done on existing Grass trimmer (nine models) to determine the natural frequencies, mode shapes, and deformation. Hence, the modal analysis was done, and it was noted that there is an increase in natural frequencies as the modes go on increasing. The natural frequency of the grass trimmer was noted at all the six modes at different lengths of the handle located from the motor and different handle angle as shown in Fig. 48.3. Maximum and minimum amplitude is considered from the ANSYS software. Here thumb rule was that the shaft should have minimum amplitude at the maximum natural frequency which

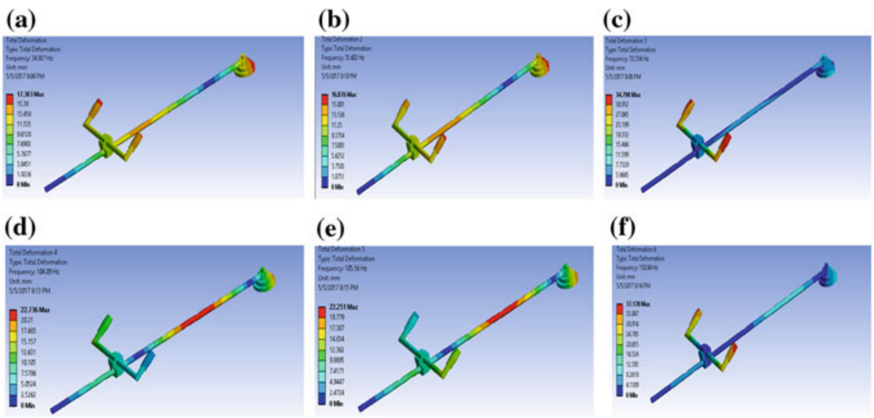

Fig. 48.3 Mode shape and natural frequency of the existing grass trimmer of model no.5 **a** 1st Mode shape @34.29 Hz, **b** 2nd Mode shape @35.602 Hz, **c** 3rd Mode shape @34.798 Hz, **d** 4th Mode shape @104.09 Hz, **e** 5th Mode shape @105.56 Hz, **f** 6th Mode shape @150.84

Table 48.3 Comparative free vibration amplitude at the different natural frequency

Model no.	Mode	Natural frequency (Hz)	Max. amplitude (mm)
1	1st(min)	33.105	18.258
	6th (max)	156.05	33.69
2	1st (min)	29.48	15.05
	3rd (max)	67.288	32.87
3	2nd (min)	33.23	18.14
	6th(max)	157.74	34.04
4	2nd (min)	35.682	16.86
	6th (max)	150.59	37.75
5	2nd (min)	35	16.87
	6th (max)	150.84	37.17
6	2nd (min)	36.05	16.38
	6th (max)	149	38.14
7	1st (min)	39	15.39
	6th (max)	124.45	7.65
8	1st (min)	41.364	16.07
	6th (max)	164.1	38.06
9	2nd (min)	42	16.16
	6th (max)	158	41

will occur at six modes of all the different length positions. From the above results, it was noted that at 1100 handle position from cutter head is found to be maximum amplitude at the natural frequency is 164 Hz and least maximum amplitude is 15.05 at 29.48 Hz natural frequency at first mode as shown in Table 48.3.

48.3.2 Modal Analysis of Newly Designed Grass Trimmer

Model analyses for the newly designed grass trimmer were determined using the ANSYS software and assumptions are considered based on the previous model by changing the material of the handle and 2.5 mm thin cover on the shaft and handle. Frequency range was given 20–400 Hz. Different natural frequencies of the newly designed grass trimmer are shown in Table 48.4, and the natural frequencies and mode shapes for the model 14 are shown in Fig. 48.4.

48.3.3 Harmonic Analysis of Existing Grass Trimmer

Harmonic analysis is a technique to determine the steady-state sinusoidal response to varying sinusoidal loads at specified frequency. Assume that the grass trimmer is

Table 48.4 Natural frequency of newly designed Grass Trimmer

Model.no	Natural frequency (Hz)					
	1st	2nd	3rd	4th	5th	6th
10	33.53	34.40	91.72	102.65	106.68	177.00
11	32.10	32.95	79.35	102.60	103.99	140.75
12	33.78	34.62	88.52	101.61	106.58	178.72
13	34.30	35.29	101.77	105.53	111.87	185.29
14	34.26	35.23	102.48	105.58	111.58	185.45
15	33.81	34.96	98.23	101.62	121.94	187.76

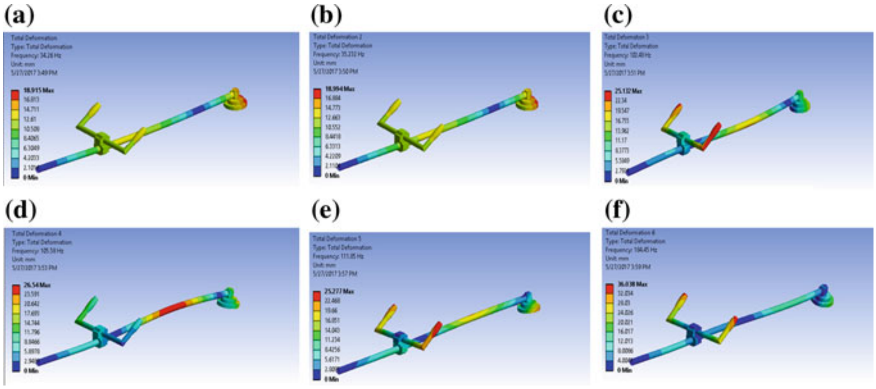

Fig. 48.4 Mode shape and natural frequency of the existing grass trimmer of model no.14 **a** 1st Mode shape @34.26 Hz, **b** 2nd Mode shape @35.23 Hz, **c** 3rd Mode shape @102.48 Hz, **d** 4th Mode shape @105.58 Hz, **e** 5th Mode shape @111.85 Hz, **f** 6th Mode shape @184.72

cantilever beam, fixed at the end of the shaft and unbalance force act at the cutter head of the grass trimmer. Here, harmonic response is to determine the frequency response of the grass trimmer in terms of amplitude (m/s^2) and it ranges from 20 to 200 Hz. Avoid the zero frequency because assume that it is flexible body.

48.3.4 Measurement, Data Collection, and Analysis

As per the recommendation of ISO 5349-1 (2001) was supervised for location of the measurement axis and vibration data is analyzed for each model via orthogonal array and calculated average acceleration for the three axes. Average of vibration amplitude (m/s^2) for the 15 models is calculated for the grass trimmer in different direction at different excitation frequency ranges. The RMS acceleration value at different excitation frequency is calculated for the optimum handle position design.

48.3.4.1 Frequency Response of Model no.5

The model shown in Fig. 48.3, the given frequency range 20–200 Hz, peak value of acceleration with magnitude 12 m/s^2 was absorbed at 155 Hz in *X*-axis. Meanwhile acceleration in *Y*-axis and *Z*-axis was 0.202 and 0.707 m/s^2, respectively, and RMS acceleration at the same frequency is 155 m/s^2. Total average value of acceleration responses in *X*-axis, *Y*-axis, and *Z*-axis was 2.5, 0.17, and 5.7 m/s^2 are shown in Fig. 48.5a respectively. Out of the nine models the handle position from the cutter is found that at 1100 mm handle position from cutter head is the optimum position in comparison of 1000 man and 1200 mm man position from the cutter in given frequency.

48.3.4.2 Frequency Response of Model No. 14

In this model given frequency range from 20 to 200 Hz, peak value of acceleration with magnitude 6.22 m/s^2 was absorbed in 155 Hz in *X*-axis. Meanwhile acceleration in *Y*-axis and *Z*-axis was 0.12 and 0.40 m/s^2, respectively, and RMS acceleration at the same frequency is 196.635 m/s^2. Total average value of acceleration in *X*-axis, *Y*-axis, and *Z*-axis was 1.027, 0.1053, and 3.05 m/s^2 are shown in Fig. 48.5b respectively.

48.4 Results and Discussion

A real-time model was designed by taking the dimensions of grass trimmer used in NIT Rourkela. By changing the different parameter like handle position from cutter head (1000, 1100, and 1200 mm) and handle angle (45°, 60°, and 90°) nine models were developed and Modal analysis was carried out to determine the natural

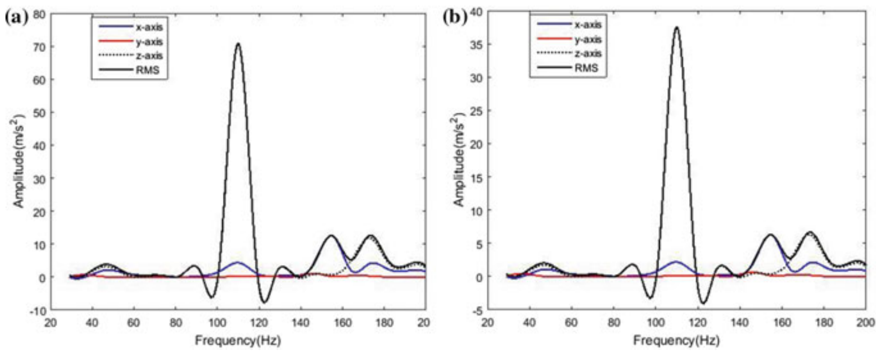

Fig. 48.5 Frequency spectra for the handle of the existing grass trimmer at *X*, *Y*, and *Z* axes for **a** model no.5 and **b** model no.14

Table 48.5 Comparative analysis of handle acceleration of Grass trimmer of a different model

Model. no.	Average acceleration m/s^2			
	X-axis	Y-axis	Z-axis	RMS of three axes
1	18.50	0.20	11.29	21.68
2	14.72	0.219	12.53	19.34
3	15.96	0.1	1.14	16
4	13.70	0.17	7.1	15.43
5.	2.05	0.21	5.7	6.06
6	11.4	0.1	2.21	11.63
7	6	1.9	3.57	7.23
8	8.31	0.21	12.18	14.75
9	25.25	0.67	5.63	25.87
10	1.63	6.71	4.72	8.36
11	0.98	6.12	6.26	8.815
12	0.75	17.87	2.26	18.03
13	2.66	5.18	4.70	7.48
14	1.02	0.10	3.02	3.2
15	3.65	6.29	1.977	7.54

frequency, mode shape, and deformation. After modal analysis, harmonic analysis was also carried out to find the handle acceleration at different excitation frequency in given frequency (20–200 Hz). Evaluate the handle acceleration at different excitation in three axes (X-axis, Y-axis, Z-axis) and the RMS acceleration of three axes was also calculated. First data were compared on the basis of handle position from cutter head (1000, 1100, and 1200 mm). It was found that 1100 mm, handle position from cutter head was optimum position because at this position average acceleration at different excitation frequency was less shown in Table 48.5.

Variation of acceleration at different excitation frequency for the different handle angle 45°, 60° and 90° and 1100 mm handle position from cutter head respectively. Average acceleration for model-4 with magnitude at handle point is 13.70, 0.17, and 7.1 m/s^2 in X-axis, Y-axis, and Z-axis, respectively. RMS value of average acceleration of three axes was with magnitude 15.43 m/s^2. Average acceleration (model-5) with magnitude at handle point is 2.05, 0.21, and 5.7 m/s^2 in X-axis, Y-axis, and Z-axis respectively. RMS value of average acceleration of three axes was with magnitude 6.06 m/s^2. In model-14 reduction of vibration in RMS value of average acceleration of (X-axis, Y-axis, and Z-axis) 2.86 m/s^2 less than that of model-5 (same handle position from cutter head and same handle angle) and variation of handle acceleration (m/s^2) at different excitation frequency shown in Table 48.5.

48.5 Conclusions

Ergonomics design of grass trimmer was carried out with the help of CATIA. Different mode shapes and deformation of grass trimmer at different natural frequency are determined by using ANSYS. Harmonic analysis was also carried out of the existing model by changing the different parameter like man position from the cutter head (1000, 1100, 1200 m) and different handle angle (45°, 60°, 90°). It was found that 1100 mm, handle position from cutter head was optimum position because at this position handle acceleration was less in comparison of 1000 and 1200 mm, handle position from cutter head. After that taking this position (1100 mm, handle position from cutter head), new handle was designed and put 2.5 mm thickness ABS and rubber on the shaft. Again free vibration analysis was done and evaluates the natural frequency of six models by changing the different angle (45°, 60°, and 90°).The harmonic analysis was also carried out to determine the handle acceleration. It was found that at handle point average acceleration in three axes was less at handle angle (60°) and RMS value of average acceleration of three axes was 47% less in comparison of existing grass trimmer

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Chapter 49
Upper Body Postural Analysis in Sitting Workplace Environment Using Microsoft Kinect V2 Sensor

Vibha Bhatia, Parveen Kalra and Jagjit Singh Randhawa

Abstract Human postural analysis is paramount to ergonomic assessment of human-workplace systems. Traditionally, motion tracking systems are being used to assess human joint kinematics in laboratory environment. Motion tracking systems with marker technology make the measurements cumbersome and limit the area of scope to constrained environments. In the present work, cheap, marker less, calibration-free, portable system using Microsoft Kinect sensor was scrutinized for its viability on human body kinematic analysis. Kinect V2 (more accurate and technologically better than Kinect V1) sensor was used to examine the body postural data of 15 participants doing a sitting job. Most of the studies are being done by placing Kinect sensor in front of the body due to occlusions. Efforts were made to assess the human body posture using side view data by placing the Kinect sensor parallel to sagittal plane of human body. Parameters like joint angles were recorded and were analyzed ergonomically for all the participants. The result of the study suggests the possible use of infrared cameras like Kinect to have some insight on human upper body ergonomic assessment in workplace environment. **Relevance to Industry**: The results obtained from the study can help the ergonomists and concerned technicians to set up better ergonomic assessment tools for workplace. The possible stakeholders of the current study are people working in offices, IT companies, call centres, accounting and analytical tasks, clerical works and all kind of sitting jobs.

49.1 Introduction

Modern-day offices comprises of extensive use of computers while working, due to which workers are desk-bound for long periods. People spend two third of their office time while sitting and their shift of sitting typically range for at least thirty minutes [1, 2]. Studies related to epidemiology have reported that enormous

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computer use and sedentary lifestyle is probable cause for increasing work-related postural problems [3, 4]. Prolonged sitting has increased the prevalence of Musculoskeletal Disorders in arms, legs, back neck and shoulders [5, 6].

To ascertain the risk of work-related MSDs in ergonomics, postural and movement information related to worker plays an important role [7]. Various tools and methods are available to determine exposure to risk factors for Musculoskeletal Disorders (MSDs). Depending upon the type of measurement technique involved they are divided as: direct measurement, self-report and observational methods [8, 9]. Direct methods are tough to implement in actual work environments due to the number of sensors attached to the worker's body [9]. Also, the wearable sensor devices usually cause discomfort and may have influence on postural activity [8]. Questionnaires, interviews, checklists and rating scales cover under self-report methods which usually are responsible for biased results [10, 11]. Other ergonomic evaluation methods like RULA and REBA are under observational methods which require the expert opinion after direct observation of the worker and workplace [12]. The input data collection in observational methods includes judgement of bodily angles using images and video frames. The data extracted by this method is mostly of low accuracy due to high variability in inter- and intra-observer data collection [13, 14].

It is quite challenging to measure bodily angles in actual work environment using motion tracking systems due to its feasibility in mass adoption. As workers do sitting shifts for long duration of time with intense arm and leg movements, observational methods (REBA/RULA) may prove to be labour-intensive and time-consuming. To phase out these problems, a computer graphic algorithm was developed to automatically detect the elbow, shoulder and wrist joint centres from field survey videos to measure shoulder abduction in 2-D [15]. The error can be controlled within 12°. It can improve efficiency and inter-rater variability in data collection. However, it's desirable to get body dynamic data in 3D which is lacking in given above algorithmic approach. The high-contrast stickers used in this approach for joint recognition from video frames may also fall off during any rigorous activity. A semi-automatic software named K2RULA based on Kinect V2 was developed which aimed at detecting awkward postures in both real-time and offline analysis [16].

From the Kinect depth camera series, Kinect V2 generation of sensor was released by Microsoft in 2014. It can infer 25 body joint centres at 30 Hz in 3-D. Kinect V2 sensor is non-intrusive, fully automatic, superfast, portable, cheap, optimally high frame rate and marker-less technology. All these features justify its feasibility for different applications and related studies, including Virtual Reality and Gaming, Natural User Interface, Healthcare, Robotics, Performing Arts, Physical Therapy, Fall detection and 3D reconstruction [17].

Other alternative techniques to study bodily angles include use of motion capture systems whose use becomes limited due to the involvement of body markers required, operational complexity and high cost of system itself [18]. Other sensors like electronic goniometers which are able to detect body angles belong to wearable technologies due to which their use become cumbersome while performing the task [19]. Relative orientation related to body part of interest with respect to another body part is effectively measured using electromagnetic trackers. Three d.o.f joints can be determined and represented quite accurately using the electromagnetic tracker technique [19].

The accuracy of Kinect has been discussed in paper by Choppin et al. [20]. The values of Median RMSE, systematic bias, maximum error and proportional error came out to be 12.6, 4.38, 58.2 and 1.15°, respectively, using IPIsoft algorithm and 13.8, 3.16, 63.1 and 1.19°, respectively, using NITE algorithm. The accuracy of Kinect was concluded to be lesser as maximum errors recorded were high if compared with already available multi-camera marker less tracking systems but Kinect's usage is well justified if used for tasks involving slower human motions where cost factor is prioritized.

The current study aims at investigating the feasibility of Kinect V2 sensor when sagittal plane of human body is aligned parallel to sensor position. Data is captured at subsequent interval of angles (60, 30, 0°) that human sagittal plane will form with respect to sensor position. The study focuses on 1. Estimation of the amount of measurement error occurring when Kinect is used to measure body angles during four different sitting body postures. 2. Detecting the angle of sagittal plane of human body with Kinect sensor which will provide the sensor measurement with less error from chosen values.

49.2 Methods

49.2.1 Subjects

Fifteen healthy participants (5 females and 10 males) from the local institute campus volunteered for the study. The participants had mean age: 25.3 years old, mean height: 170 cm, mean weight: 67 kg. Participants had no prior history related to occurrence of MSDs. All the participants used right hand as their dominant hand. Experimental protocol and purpose of the experimentation were explained in advance to the participants. All participants' consent was taken on written informed consent form for taking part in the experimentation.

49.2.2 System Overview

The system proposed by us consists of Microsoft Kinect V2 sensor for windows, the PC system with windows 8.1, 64 bit, 8gb RAM, Intel core i5 processor @2.2Ghz. The LabView 2013 was used as a programming platform to capture 3D image depth data. Libraries to track body joint centre data using Kinect were downloaded from VI Package manager software 2017. The electronic goniometers by Biometrics Ltd. were used at sampling frequency of 50 Hz to measure flexion/

extension (leading to angle change) at the elbow and the knee joint centres. The data was recorded by Biometrics Data Logger.

49.2.3 Experimental Design

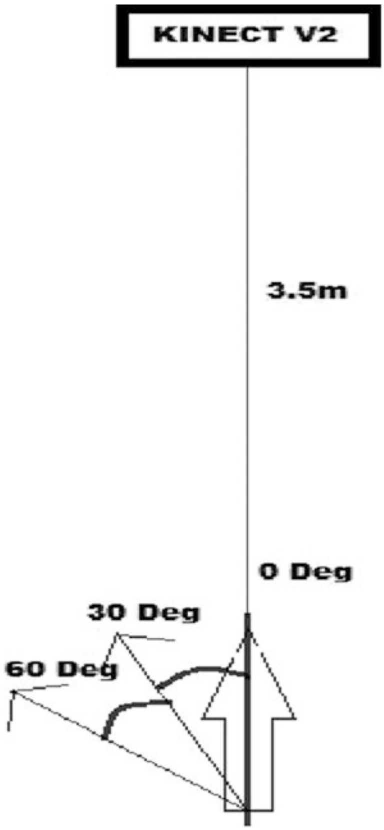
Data collection: The experimental trials were taken on simulated workstation which mimicked the real workstation. The simulated environment consisted of an office chair (with back/elbow support) and table. The readings were recorded for four different commonly followed office postures (normal sitting, writing, picking something from table and relaxing postures). The Kinect sensor was placed at 3.5 m distance from the chair centre position and at 1.1 m height from the ground as shown in Fig. 49.1. The tilt angle of the kinect sensor was adjusted so that it may take readings for full body skeletal both in standing and sitting position of the participant. Readings were recorded at 60, 30 and 0° angles between the plane

Fig. 49.1 Placement of kinect sensor w.r.t. chair position

formed due to kinect position and chair centre with the plane formed by the person's sagittal plane when his body is facing different directions which are shown in Fig. 49.2. Each participant performed each possible combination of the task twice. The kinect sensor collected the data at 30 fps with the help of LabView interface developed to detect each body joint and calculate the angles at elbow(angle formed by vector of shoulder and elbow centre points with the vector of wrist and elbow centre points) and knee joint centres. Spline Interpolation was done to up sample the data to 50 Hz. Simultaneously, electro goniometer was used to collect the data at two body joint centres (elbow and knee joints) at 50 Hz as shown in Fig. 49.3. The readings from the electro goniometer were considered as the gold standard for the current study. Participants were instructed to maintain the each static sitting posture for 15 s data collection from both kinect and goniometer sensors. The flowchart shows the procedure followed for the current study in Fig. 49.4. Figure 49.5a–d shows the skeletal data captured using LabView interface for Kinect for four different postures taken in the current study.

Data Processing and Analysis: Outlier values were detected and removed statistically. Fifty relevant values from each possible data set (kinect sensor and

Fig. 49.2 Kinect-chair orientations (0, 30 and 60°), arrowhead shows the direction that participant is facing



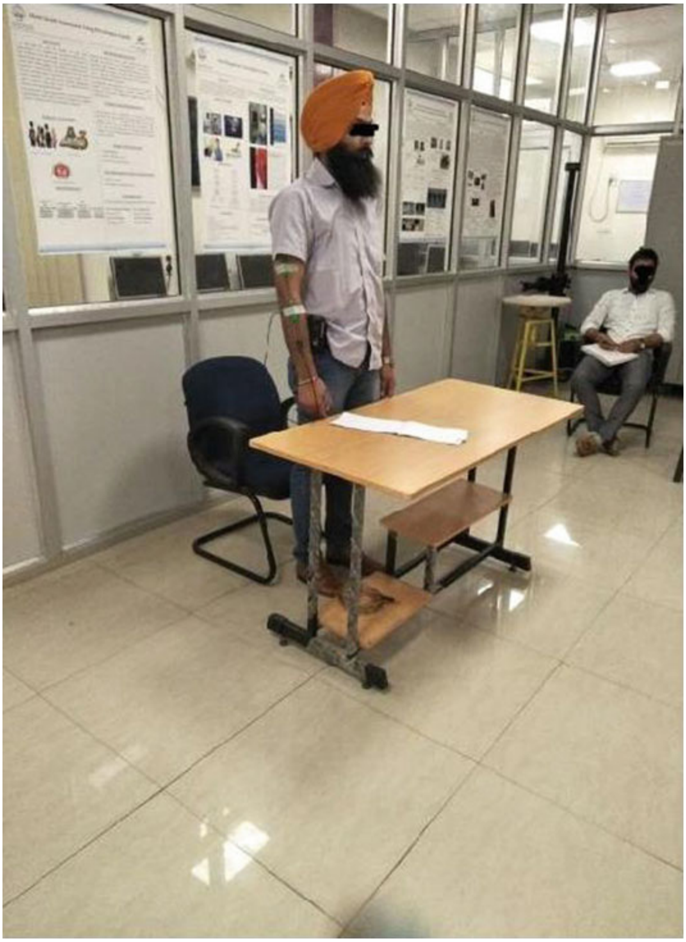


Fig. 49.3 Electro goniometer placement on the elbow

goniometer readings) were extracted to take the mean values. For each angle orientation of the chair with respect to kinect sensor position (60, 30 and 0°), the Root Mean Square Error (RMSE) values, Correlation coefficient (r) and concordance correlation coefficient (rc) between kinect-based and goniometer-based readings were calculated. These measures give the evidence for concurrent validity analysis [17].

49.3 Result

The Root Mean Square Error(RMSE) values, Correlation coefficient (r) and concordance correlation coefficient (rc) between kinect-based and goniometer-based readings are summarized in the table given below as Table 49.1.

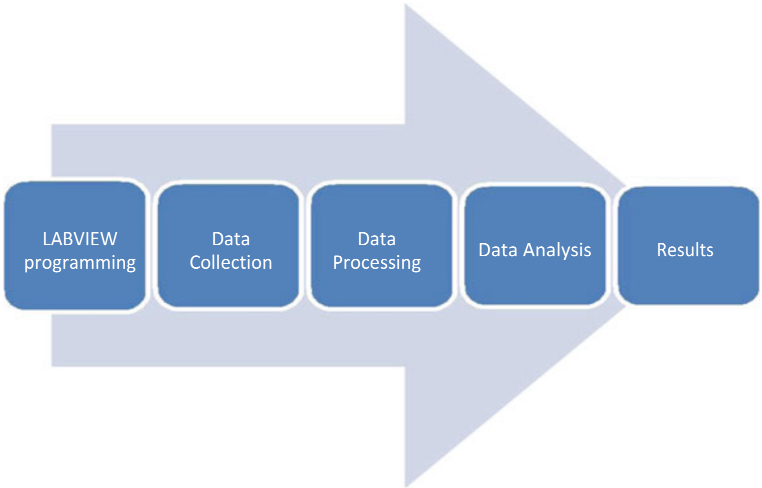


Fig. 49.4 Flowchart of experimental procedure

The results of the current study indicate that the Kinect sensor gave more accurate values for elbow body joint centre angle values than the angle values obtained at the knee body joint centre. The RMSE values for elbow joint angles for all 60, 30 and 0° orientation came out to be lesser than corresponding RMSE values for knee joint angles. The least error (RMSE is less than 10°) was reported for values of elbow joint centre values when the Kinect was placed in front of the participant while the maximum error was reported in the case for knee joint centre angle values when the kinect orientation was 60° (RMSE is more than 15°).

For all the orientation of the kinect sensor, when the sensor was at 0° orientation (front of the participant), it produced stronger concordance correlation coefficients for both elbow and knee body joint centres. Therefore, the results suggested that placing the kinect sensor in front of the camera yielded better results out of all the orientations and its accuracy subsequently reduced with the increase in the angle orientation of the kinect with respect to person's orientation.

Kinect sensor overestimated the angle values than those obtained by the electro goniometer in elbow joint centre data collection in most of the cases ($p < 0.01$) as shown in the graph in Fig. 49.6a, whereas the angle values by Kinect sensor were less than those obtained by the gold standard when the angle data was collected for knee joint centre but the p values lesser than 0.03 were obtained in all cases except for the third sitting posture in all the orientations of the kinect and chair (60, 30 and 0°) as shown in Fig. 49.6b.

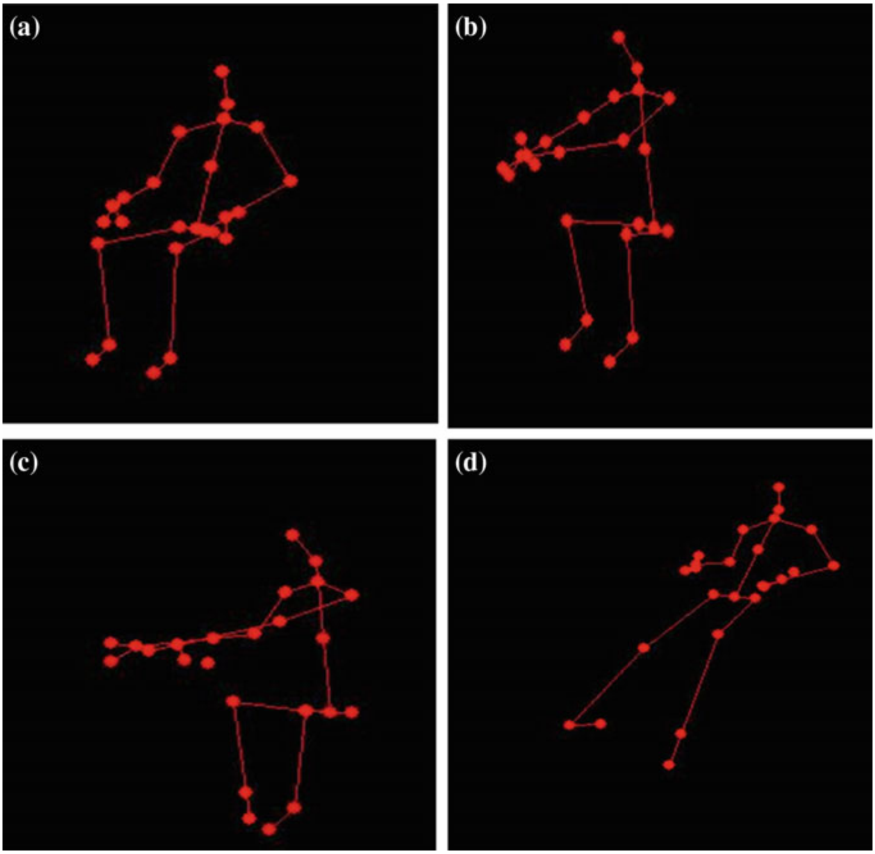


Fig. 49.5 Skeletal information obtained from LabView interface for postures recorded during **a** normal sitting **b** writing **c** picking (something from table) **d** relaxing

Table 49.1 Root mean square error (RMSE) values, correlation coefficient (r) and concordance correlation coefficient (rc) between kinect-based and goniometer-based readings at various orientations (60, 30 and 0°)

Kinect's orientation w. r. t chair				
Joint center		60°	30°	0°
Elbow	r	0.905	0.914	0.943
	rc	0.757	0.770	0.825
	RMSE	13.038	11.069	9.736
Knee	r	0.636	0.716	0.810
	rc	0.476	0.576	0.655
	RMSE	15.414	13.418	12.003

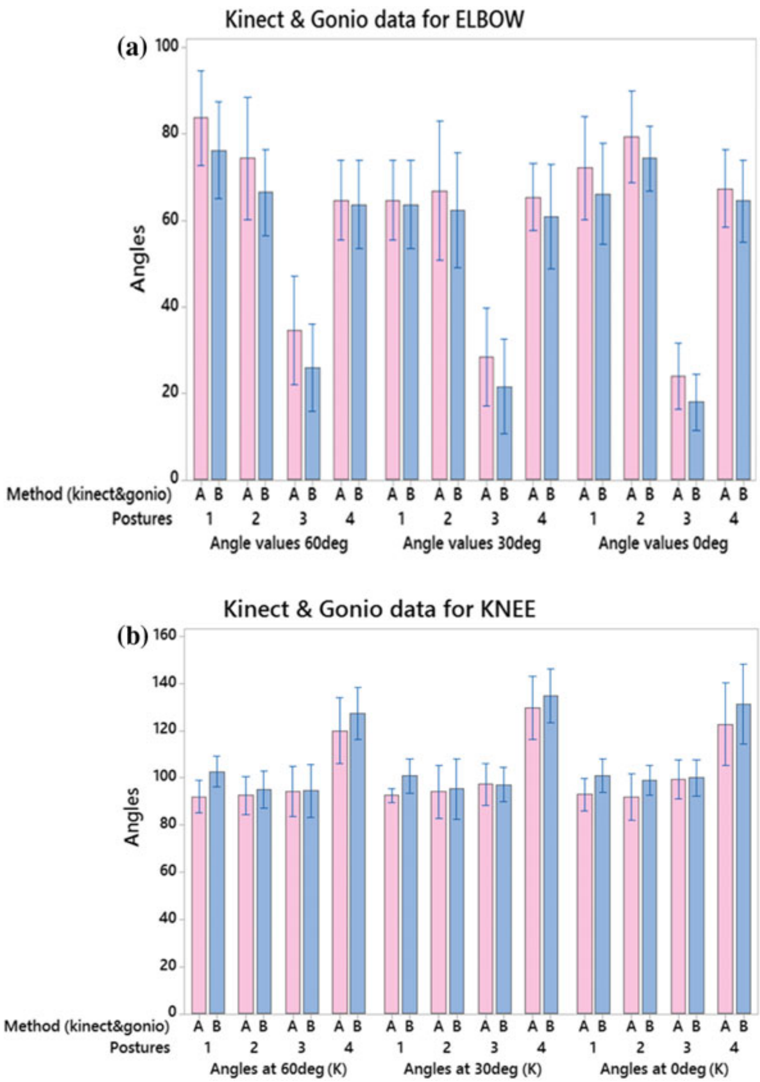


Fig. 49.6 A-Kinect data, B-Goniometer data in joint angle measurement of **a** elbow **b** knee at 60, 30 and 0° orientation. *Note* Normal sitting, writing, picking something and relaxing postures are represented as 1, 2, 3 and 4, respectively

49.4 Discussion

The current study aimed at understanding the feasibility of the kinect sensor to measure body angles at the possible side views orientations, so as to get the better understanding of body kinematics. Great range of validity was observed in the results of the study. The correlation coefficient ranged from 0.6 to 0.9, and the concordance correlation ranged from 0.4 to 0.8. This gives the strong evidence that the kinect-based joint angle measurement values are positively correlated to electro goniometer-based joint angle measurements and thus showing positive agreement between two measurement systems overall.

In the present study, the correlation coefficients values ranged on the higher end (near to 1) than the study by Pfister et al. [21] which ranged from 0.04 to 0.77. This may be due to the reason that the correlation in that study was found out when the task was dynamic in nature unlike the static postures considered in current study, moreover, motion tracking system was taken as the gold standard. The RMSE across all the volunteers ranged from 9.7 to 15.4° which are comparable but bit less than the values obtained in the study by Pfister et al. [21].

The more correlation seen in the body joint centre values for the elbow joint is maybe due to the reason that while capturing the data of knee joint angle values the workstation edges(table used in the study) hindered the kinect perspective view and gave some variable results. This also shows the possible reason for lower RMSE values in elbow joint angle values than the knee joint angle values.

The RMSE value at 60° was more than the RMSE value at 0 and 30° which shows the higher acceptability of the kinect sensor data when the person is facing the kinect sensor. The RMSE values increased with increase in orientation angle which may be present due to interference of the body joints leading to occluded data. But the increased RMSE values still seemed optimally feasible enough to be considered for angle value estimation if demanded by workplace analysis for these orientations. The overestimation observed in most of the values of kinect data may be possible due to tilt in the kinect sensor. The studies which show no such estimation are mostly done when kinect sensor is placed with its optical axis parallel to the ground. The study by Dutta [22] showed non-homogeneity in measurement error in measurement volume by kinect. Measurement errors along with the three different co-ordinates of the kinect sensor may be responsible for results with the proportional error.

The angle measurements with kinect sensor came out to be less accurate if we consider goniometer data as gold standard, but kinect angle data still proved its potential for such measurements as an alternative to other systems. If the current error data is compared with the human observational error observed in the study by van Wyk [23], kinect data showed less errors. Kinect sensor appears to be more efficient measure for angle data collection than human observation.

It seemed from the current study that the kinect sensor can be used as the tool to measure the body angles while doing tasks in sitting postures in related workstations. Further these, body angles define the postures and may detect awkward postures which lead to musculoskeletal disorders while doing sitting jobs for longer duration.

The results obtained in this study are constrained due to some limitations of the current study. The current study was carried out in ideal environment of lab settings which made it easy for the kinect sensor to detect the body movements. Further, participants were made to follow some protocol to standardize the study which is not possible in the real work environment. Many other factors can affect the results in reality like placement of objects on the real workstation, nature and type of task, size and shape of the workstation, lightening conditions etc. These factors are expected to give errors in the body movement analysis with current possible setup of kinect. To protect the intimacy of the participants, experiment was performed when participants were wearing full clothes which can be possible for some error in angle calculation as kinect scans the full body surface for joint estimation. Electro goniometers can only be attached in the ideal experimentation like in current study; otherwise, it may create hindrance to work in actual job tasks. Other postures like overhead reaching postures and more demanding postures are not included in the current study, so appropriate care may be taken in use of kinect sensor for such tasks.

49.5 Conclusion

The large range validity of kinect sensor data (3-D) among the various kinect orientations has been found out considering various sitting postures and different body joint data. Kinect sensor placement in front can provide data with fewer errors than the other angular orientations but the data obtained with other orientations also seemed optimally feasible to use in demanding situations in real work environment where sensor placement is the major concern. The data obtained using kinect sensor can be used to have proper placement for the devices used in sitting workplace which may prevent awkward postures and may help in reducing musculoskeletal disorders in the long run.

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Chapter 50
To Analyze the Impact of Spokesperson Used in Cosmetic Advertisements for Trust Building of the Indian Customers Buying Intention

Sushmita Jadhav, Rushab Kataria and Dandeswar Bisoyi

Abstract Advertising has developed to be one of the prominent business exercises in the cutting edge world which helps to increase consumption of goods and products, therefore, having straight outcome on the economy. The spokesperson in advertisements can make the communication process extra effective when they are used according to the participation of the consumer. The intention of this study was to survey the influence of advertising spokesperson on trust building and purchase intention of the customer over a digital platform. The second motive of this paper was to inspect the relationship between customer's trust and spokesperson in Indian advertisement. Man–Whitney U test was selected for hypothesis testing and variance between the expert and celebrity spokesperson was studied. The results disclosed that the purchase intentions are more positive for celebrity spokesperson advertisement, hence suggesting celebrity spokesperson is an effective way to raise consumer trust and increase their purchase intention for the product.

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50.1 Introduction

The Digital advertisement[1] is an expression that denotes the advertising that involves computational networks. The plan of advertisements is to present information to potential customers who might end up buying the product or at least be interested in the brand. The main aim of advertising, many believe is to sell an entire analysis of advertising and limited time exercises. The essential purpose for this study is to understand how digital advertisements are developing the reasoning and conduct of consumer. This research portrays that where organizations were before the innovation of digital advertisements ideas and where they are ranked today and how we are raising the value of our regarded target group of consumers. The most vital motive of this research was to ensure the dependence of all of these factors on each other and how a positive stage can be made for clients that they can begin taking digital advertisements a crucial stage for getting the data with respect to the items and services.

The fundamental motivation behind this study is to check how this stage gives better alternative and approaches to clients so as to settle on successful choice in regards to buy or not. Also, to check the impact of Expert and Celebrity spokesperson on Trust building. The second most essential angle to be checked in the paper was the impact of expert and celebrity spokesperson on purchase purpose. The third most vital goal was to check the effect of celebs expert spokesperson in digital advertisements.

50.2 Literature Review

Today's customer is aware and influenced by media. Celebrities are adored as icons now. If the customer knows the physical attractiveness, credibility and the match between celebrity and the product to be favorable, he is passively being influenced to like that product which leads to the purchase of that product. Features of the product itself take secondary importance [7].

Celebrity endorsement as consumer perception remains same when we have one celebrity or when we have multiple celebrities in high involvement product ads so for advertiser and dealers of great connection product or service argument should be of prime concern compared to number of celebrities in an ad. While for low involvement product and services, multiple celebrities' endorsement can play its magic but points should be considered before going for more than one celebrity in an ad [6].

Approach toward the promotion and brand are the most widely known measures of individuals' states of mind that are created partially because of review advertisements.

[1]Includes contextual ads on search engine result pages, banner ads, Rich Media Ads, Social network advertising, interstitial ads, online classified advertising, advertising networks and e-mail marketing, including e-mail spam etc. [2].

Regardless of the fact that there might be various measurements of adoring for advertisements, the most interest in a worldwide reaction of liking disliking instead of to the complexities of measurements of liking or parts of the precursors to the liking. The same rather worldwide conceptualization of approach toward the brand was likewise favored here.

Gathered information on seven dependent variables (promoter acceptability, sponsor validity, representative trustworthiness, representative believability, mark disposition, demeanor toward the ad, and purchase expectation). The coordinate theory predicts a celebrity engaging quality by product type interaction. The anticipated association was found for just two of the seven dependent variables, and, critical to note, not found for brand attitude nor for purchase expectations. We trust that different angles/qualities of the endorser, (for example, skill) might be more strong (give a chance to more prominent fit) than physical appeal. An upgraded part of aptitude is steady with later work on the coordinate theory [1].

50.3 Theoretical Framework

In this research, the effect of trust on purchase intention is studied toward expert spokesperson and celebrity spokesperson. The independent expert and celebrity spokesperson's effect on dependent variable trust and purchase intention is studied (Fig. 50.1).

50.3.1 Research Hypothesis

$H_{1\text{-}0}$ Expert spokespersons in Indian advertisement have no significantly positive effect on trust among the Indian customers.
$H_{1\text{-}1}$ Celebrity spokespersons in Indian advertisement have a significantly positive effect on trust among the Indian customers.

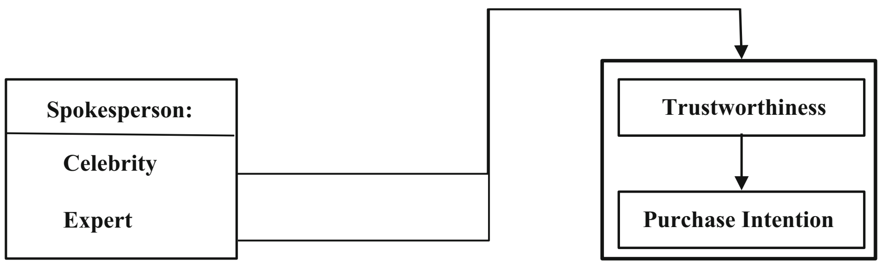

Fig. 50.1 Conceptual structure of study

$H_{2\text{-}0}$ Celebrity advertising spokespersons have no significantly positive purchase intention of Indian customers more than expert advertising spokespersons.
$H_{2\text{-}1}$ Celebrity advertising spokespersons have significantly positive purchase intention of Indian customers more than expert advertising spokespersons.
$H_{3\text{-}0}$ Trustworthiness has no significantly positive effect on purchase intention with respect to the Indian advertisements
$H_{3\text{-}1}$ Trustworthiness has a significantly positive effect on purchase intention with respect to the Indian advertisements.

50.4 Methodology

50.4.1 Conceptual Structure

This study targets to deliberate the properties of using celebrity spokesperson and an expert spokesperson in an advertisement. The effects of both the spokespersons on the trustworthiness of the customer on the product are also tried to discover. Also, discuss whether or not the involvement of celebrity and expert spokesperson makes any contribution to purchase intentions and determine which has a better effect.

50.4.2 Variable Design and Measurement

Advertising Spokesperson is a publicizing endorser who utilizes his/her own particular fame to exhibit the advantages that purchasers can value through publicizing exercises as believed by. Be that as it may, there are four kinds of publicizing spokespersons which were stated by Freiden, this examination embraces two sorts of promoting spokespersons, celebrity, and experts. The meaning of Expert with a reference to open or acclaimed figures. Companies ordinarily anticipate that customers will develop into more empathic through the high ubiquity or fascination of a big name and after that vibe great about the items being suggested was said in an examination as mentioned by.

Expert Spokesperson refers to an individual who is an expert in his/her own proficient field. He/she may have proficient information in identifying with the items being prescribed. This research suggests to them as people with proficient information of and involvement in PDAs. For this situation, the expert chosen are doctors.

Celebrity Spokesperson refers to popular big name having a particular fame to exhibit the advantages that purchasers can value through publicizing exercises. “When the public knows someone and admires them for their successes in the fields other than advertisements can be claimed as a celebrity endorser” as stated by

L. Friedman and H. H. Friedman in 1791. In this case from Bollywood industry or the Indian film industry who are celebrated locally and remote motion picture.

Purchase Intention is identified with the conduct, perception, and states of mind of consumers. Purchase behavior is a key point for consumers to and assesses the particular item. States that purchase intention is a powerful method to foresee purchasing process. It can likewise be characterized as a measure of the quality of one's aim to play out a particular conduct or settle on the choice to purchase an item or service.

Trustworthiness of the item which depicts dependability here is thought to be the conduct of the consumer trusting that the item will work as surely guaranteed in the advertisement. It can likewise be expressed as the message recipient's in spite of user thinking a superior need than considering a message from a specialist expert source who was low reliability. That is, if a prospective client can make certain that an expert source will give correct information as a result of his or her high dependability, they may deny the effortful endeavor of examining the message and, rather, discourteously acknowledge the conclusion as substantial. In distinction, if a prospective customer isn't sure with reference to whether an expert source will convey precise data due to the source's low or flawed reliability, he or she might need to examine the conflicts to see whether the correspondence is to make sure canny and honest to goodness.

Advertisement selected for this study was a then un-launched advertisement. An anti-dandruff shampoo advertisement was chosen for the research study. The shampoo brand selected was Scalpe Plus. The original advertisement comprised of a doctor, i.e., an expert in the advertisement who spoke about the scalp problems and issues. The expert further talks about how the shampoo works better for the scalp issues and promotes its usage. There was no celebrity used in this advertisement.

For the controlled experiment setup, the same advertisement was edited to use an Indian celebrity into the advertisement replacing the doctor from the advertisement. The design and setup of the advertisement changed where the respective spokesperson addressed about the scalp issues but the outcome message and the product promotion wherein how the product fights the issues were kept constant for the study purpose. This was completed to acquire an unbiased data.

50.4.3 Experiment Design

This study was conducted in a controlled experimental format with two experimental variables to study and research upon. The first variable is the trustworthiness and second the purchase intention. The effect of which was studied using the advertising spokesperson which was again classified as celebrity and expert spokesperson. Students from two Indian universities were chosen for the experiment. An anti-dandruff shampoo was chosen as a product. The advertisement chosen for this study promoted an anti-dandruff shampoo as a product endorsed by a celebrity spokesperson and an expert spokesperson was used in the edited advertisement. The brand of this anti-dandruff shampoo was Scalpe Plus.

Before the actual study was conducted, 60 students were interviewed as a part of the pre-study conducted before the main research. The purpose of this pilot study was to ensure the direction of research including the selection of brand and the important properties of the product to consider while conducting the main study. Which later guided in the questionnaire reframing and listing product qualities for the main study. The pre-study helped us in figuring out an appropriate cosmetic product which is not gender-biased and has a celebrity that is well known and influential in the advertisement chosen for the experimental research.

50.4.4 Data Collection and Analysis Method

This study took university students from two multicultural universities in India as subjects. The universities selected were: Symbiosis University and MIT ADT University. The convenient sampling method was chosen for the experiment and distributing questionnaires. A total of 120 students which aged between 18 to 25 years were distributed questionnaires to, 60 from each university were shown the advertisement and then the questionnaires were filled. Out of the 60 from each university were divided into two groups randomly and each group was shown an advertisement endorsing the shampoo by Celebrity and Expert respectively.

Data was analyzed by SPSS 20. Reliability and validity check were first run in order to get the precise data to study upon. After which the unreliable data was canceled and then the required data was studied. Normality of the data was then checked in so that we understand the further tests to be carried on. Co-relation among all the variables was tested to get the actual variables to be studied upon. Factor analysis was then run to determine the relationship between the trustworthiness of the celebrity and its influence on the consumer's purchase intention.

For measuring the change in the consumer purchase intention of the product and trustworthiness of the celebrity endorsing the product in the advertisement, since the variables were dependent and independent Man–Whitney U test was applied.

50.5 Results

50.5.1 Sample Description

Celebrity Advertisement Experiment Of the respondents (56%) surveyed were female and (44%) of the total population was male. From the total response received (60) in the group which had been shown the celebrity spokesperson advertisement, 8 and 10 number of respondents were aged 19–23 and 24–25, respectively. 5, 4, 9, 7 number of respondents were aged 18, 20, 21, 22 years, respectively. The awareness of the advertisement among the respondents was 1.66% and the understandability of the message conveyed in the advertisement was 97.77%.

Expert Advertisement Experiment Of the respondents (41%) surveyed were female and (59%) were male. Out of the complete number of respondents (60) in the group which had been shown the expert spokesperson advertisement, 7 and 14 number of respondents were aged 18–20 and 19–21, respectively. 5, 8, 5 number of respondents were aged 22, 23, 25 years, respectively. The awareness of the advertisement among the respondents was 6.66 and 98.33% respondents understood the message that we were trying to deliver in the advertisement.

50.5.1.1 Gender

See Table 50.1.

50.5.1.2 Standout Factor

See Table 50.2.

50.5.2 *Reliability Analysis*

The results of the reliability tests stated that the Cronbach's α values for effect of expert and celebrity on trust and purchase intention are 0.857 and 0.796 which meets the criteria set by of the values being higher than 0.7. Thus, we will conclude that the questionnaire used for this study has high reliability (Table 50.3).

Table 50.1 Gender data in the population

		Frequency	Percent	Valid percent	Cumulative percent
Celebrity	Male	26	44	44	44
	Female	34	56	56	56
	Total	60	100	100	100
Expert	Male	35	59	59	59
	Female	25	41	41	41
	Total	60	100	100	100

Table 50.2 Standout factor in the advertisement with its factors

		Frequency	Percent	Valid percent	Cumulative percent
Celebrity	Spokesperson	39	65	65	**65**
	Graphical visualization	8	13.33	13.33	78.33
	Product	10	16.67	16.67	95
	Branding	3	5	5	100
	Total	60	100	100	
Expert	Spokesperson	4	6.66	6.66	**6.66**
	Graphical visualization	35	58.33	58.33	64.99
	Product	13	21.66	21.66	86.65
	Branding	8	13.35	13.35	100
	Total	60	100	100	

Table 50.3 Reliability analysis

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
0.857	0.796	5

50.5.3 Hypothesis Testing

For Celebrity advertisements group, among the people interviewed by us showed the celebrity spokesperson advertisement to 76.3% of the respondents stated their belief on the advertisement is because of the celebrity spokesperson used in the advertisement. While the standout element in the advertisement shown to the respondents, 65% was voted in behalf of the celebrity spokesperson. The expected workability of the product based on the advertisement shown was 63.3% out of which the number of positive workability respondents said the presence of celebrity contributed to 45%. The purchase intention of the respondents was measured to be 67.2% and the remaining 32.8% who won't purchase the product the reason was concluded that maximum of them won't need such a product in their daily lives or have no requirement anytime soon. The final recommendations received for the product was counted to be 93.4% irrespective of the purchase intention being positive or negative.

For Expert advertisements group from the final complete respondents interviewed and shown the celebrity spokesperson advertisement to 58.33% of the respondents expressed their conviction on the promotion is because of the celebrity representative in the notice. While the standout element in the advertisement shown to the respondents, 6.66% was voted in behalf of the celebrity spokesperson. The expected workability of the product based on the advertisement shown was only 15% out of which the number of positive workability respondents said so due to the existence of celebrity spokesperson in the adv. was insignificant. The intention for buying the product by the respondents was measured to be 45% and the remaining 55% who won't purchase the product the reason was concluded that maximum of them won't need such a product in their daily lives or hit assumed that it will be nil or zero in the upcoming time period. The total number of recommendations for the product was counted to be 21.66% even if the purchase intention would be either positive or negative.

The Hypothesis that were proved in this study are:

$H_{1\text{-}1}$ Celebrity spokespersons in Indian advertisement have a significantly positive effect on trust among the Indian customers.
$H_{2\text{-}1}$ Celebrity advertising spokespersons have significantly positive purchase intention of Indian customers more than expert advertising spokespersons.
$H_{3\text{-}1}$ Trustworthiness has a significantly positive effect on purchase intention with respect to the Indian advertisements.

50.5.3.1 Effect of Celebrity Spokesperson on Purchase Intention

The significance value is calculated to be 1.62 which is higher than the value for expert spokesperson, and hence, the null hypothesis was rejected and the effect of celebrity spokesperson on purchase intention is found to be significant.

50.5.3.2 Effect of Expert Spokesperson on Purchase Intention

The significance value is calculated to be 1.20 which is lower than the value for celebrity spokesperson, and hence, the null hypothesis was accepted and the effect of expert spokesperson on purchase intention is not found to be significant.

50.5.3.3 Effect of Celebrity Spokesperson on Trust

The significance value is calculated to be 3.70 which is higher than the value for expert spokesperson, and hence, the null hypothesis was rejected and the effect of celebrity spokesperson on trust generated on the product is found to be highly significant than the trust on the product endorsed by expert spokesperson in the advertisement.

50.5.3.4 Effect of Expert Spokesperson on Trust

The significance value is calculated to be 1.095 which is lower than the value for celebrity spokesperson, and hence, the null hypothesis was accepted and the effect of expert spokesperson on trust generated on the product is not found to be significant on the product endorsed by celebrity spokesperson in the advertisement.

50.6 Discussion

50.6.1 Theoretical Justification

Lately, the learning through digital advertisements is mainly focused on an individual's personal decision. TVC plays a very essential part so as to change the exposure of the advertisements of everyone socially and financially. It gives imperative data identified with the different moments. The advertisements give data identified with everything either it's a little device or it is an auto. People can get information about each one of these things by sitting at their homes with no issue. In this way, people are exceedingly cognizant while seeing the advertisements. They just incline toward those advertisements that are for their most loved brand. If any customer isn't occupied with any brand, yet simultaneously they are searching for the nature of data that is being portrayed in the advertisement and great utilization of claims. Negative impact can overcome in one circumstance when spokesperson is not giving data as indicated by the prerequisites of the customers.

The main thing that pulls in the customer toward the specific brand is great utilization of spokespersons, movements, music, requests. The awareness of customers or the prospective buyers of the product keeps changing from time to time. They just tend to bias toward those products that are of high quality and it causes no impact on their body. Promoters should remember the psychological circumstance of customers and spotlight in the fixings to expand their levels of trust on the brand through the advertisements to increase the purchase intention.

50.6.2 Conclusion

As can be concluded from the outcomes, celebrity advertisement has a significant effect on clients according to their perspective and purchase intention. Celebrity support has turned out as a powerful factor as well as rather a causal factor in the consequences in this study. Physical engaging quality, validity, and compatibility of big celebrity name with reference to the embraced commercial all have effect on the respondent's observation about the advertised item. The tests have overall bore great noteworthy outcomes in light of factors utilized. In this way, celebrity supports do bring about deals climb. Consequently, the up and about pattern of the advertisement nowadays. Another implication in this study is that it goes out to show how much the present customer knows and influenced by media. Celebrity is revered as symbols now. On the off chance that the client sees the physical allure, believability, and the match among big name and the item to be positive, he is idly being affected to like that item which prompts the buy of that item. Features of the thing itself take discretionary essentialness.

50.7 Implication

50.7.1 Limitation

The design and outline of this study were tried to be more unbiased and true as possible. The conclusion although has a few limitations. This research was limited to its field of study and the scope of selection of the sample. In the collection of data, even if both questionnaire and interview methods are used, subjects could be answered in bias and in terms of their personal subjectivities, which is quite impossible to receive their real ideas, so it is also a limitation of this study. For the convenience of making this research, it used the college-going students from just two universities are also a limitation of this research as the variables of consumer purchase intention and trustworthiness. This research study concentrated on the respondents' quick reaction to the advertisements. The student's responses may have been extraordinary in the cases that they had over and again viewed an advertisement for a more extended timeframe. These limitations may have caused deviations in the conclusions obtained from this study.

50.7.2 Future Study

The accompanying recommendations are made as reference for researchers who are keen on leading consequent examinations in this field of study: (1) Conducting the same study over more sample size would help in getting more perfect results. (2) The celebrity used can also be a limitation there can be a test performed by using multiple celebrities or by using more advertisements and more time frames. (3) Different age group can be changed to see the inference between the age and the factors. (4) The research product used in this study was a shampoo and various other variants of the products range and other cosmetics can also be considered or studied as a continuation to this research to have more in-depth knowledge of the results concluded. (5) Various advertising approaches and designs can be utilized for generalizing the results for particular set of products and relevant comparisons can be made.

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Chapter 51
Impact of Topological Perception on Attention for Products Shape

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Abstract A primitive and general function of the visual system is the perception of global topological properties. People will give priority to attending the global topological properties of object compared with the local geometric properties. The purpose of this paper is to verify whether topological properties perception is applicable to product recognition. If the topological properties variation occurs in the shape of the product, the product will get much attention, and the product will have the opportunity to be aware of the innovations that cannot be felt by the vision, such as function, experience, and so on. Therefore, topological properties perception is helpful to product innovation. Therefore, this study hypothesized that the perception of topological properties (holes, connectivity, and inside/outside) exists in the shapes of the products, and human can pay attention to the products that are relational to the variation of topological transformation occurred in the shapes. From the experiment of bicycles recognition, we ascertain people will pay attention to the bicycles with the topological properties variation. Repertory grid technique can find out the reasons for attention and distinguish them. We extracted the mental constructs of the participants for the products with topological variation and identified the reason of visual attention.

51.1 Introduction

51.1.1 The Recognition of Product Innovation

Product innovation is the important strategic tool in the competitive market [10]. In general, consumers have no access to the designers of the products they buy. Their

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interpretation of design is based predominantly on their interaction with the product [14]. Under normal circumstances, the relationship between a person and a product begins with the visual appearance of the product. Customers tend to identify the features of a product through its visual form, including esthetic impression, semantic interpretation, and symbolic association [5]. People also match their expectations and level of novelty with a product's usability [11]. By manipulating the appearance of products, a designer can elicit certain emotions from or introduce beliefs to users [9]. In this sense, a product's visual form plays an important role.

The composition of the product form consists of colors, materials, shapes, and proportions [19]. Shape is probably the first factor and the most significant property of a product that one can perceive from objects [15]. After all, industrial designers generally start with sketches of shape, and not the identification of color, in developing new products.

As products in the same product category should be explicitly distinct from competing products, a product's shape is often the first consideration in distinguishing it from other products in the market [21]. The original intention that selecting object comes from the personal preference for shape, just like an influence on people's attitude toward the objects with sharp angled or curved, and more preference of curved visual objects [1]. Meanwhile, people use new form to draw on existing products and develop a new schema [19]. In the development of a new product, the emotional value of the product is likewise an important factor. A biomimetic shape in product design has been found to meet the emotional needs of people [22].

Although product shape perceived by the senses has been studied for decades, the focus has been on the esthetic, semantic, and symbolic aspects of shape [4]. This work focuses on attention on product shape, on the premise that customers make unconscious comparisons between competing products based on their visual forms or according to their memory of the product prototype. Another case is the comparison of the reality of the product and the imagined model (e.g. the appearance of product comes from empirical perception). If the actual product is similar or more attractive than the imagined model, the consumer will recognize the designer's vision quickly. Thus, how can the product gain an attention? This requires understanding of the object recognition rules of people.

51.1.2 Topological Perception

Topology is a major branch of mathematics. It is concerned with the properties of space that are preserved under one-to-one and continuous transformations, such as stretching and bending, but not breaking or fusing. Important topological properties include connectedness and compactness. From the perspective of topology, solid figures (e.g., a cube and a tetrahedron) are all equivalent to each other. The reason is that each of them can be modified to match any other by continuous transformation. An attribute of an object will be called a topological invariant if it does not change under a continuous transformation. Most of the commodity of our lives is homeomorphism to spheres and rings.

There are two most basic propositions about the beginning of the visual process in the study of perception: early feature analysis and early holistic registration. The viewpoint of early feature analysis proposes that perceptual processing is from local elements as the features to be integrated into wholes [20]. Early holistic registration holds that perceptual processing is from global to local, global property of a visual scene precedes analysis of local features [13, 16]. Nevertheless, the proposal of topological perception [2] makes sizable impact on visual perception [17]. Topological invariants can verify that global properties are sometimes perceived better than local ones and thus might be basic [18]. In real world, topological invariant attributes can be described as three kinds of topological properties in two-dimensional manifold: connectivity, number of holes, and inside–outside relationship [3]. 2D manifold is also called surface. Plane, sphere, and torus are all 2D manifold.

51.1.3 Repertory Grid Technique (RGT)

The present study applies the existing topological perception theory to the research of product shape. It is a big leap that the objects recognition from figure to the shape of product. After all, the product contains many elements, the shape is only one part of the complex system, and the shape has various relationships with the other elements. The study of the shape of product includes the category of the two-dimensional graphics. Furthermore, topology is especially unfamiliar to the ordinary people, and it is almost impossible to say “topology” directly from their mouths. It is very difficult to get the effect of topological properties on visual perception in the shape of product. Therefore, we must find a research method that can detect those thoughts or ideas hidden in the heart of individuals, and repertory grid technique is more suitable for such research.

RGT is derived from the personal construct theory of cognitive psychologist George Kelly in around 1955. It is looked as a psychological technique by researchers to explore the psychological cognitive structure hidden in the depth of the individual. RGT provides an excellent way of quantifying people’s attitudes, feeling, and perceptions [7].

Kelly claimed that people could develop their personal criteria’s construct for construing things when they were feeling things in phenomenal world. In the process of distinguishing things, a person relies on his or her construct. The construct is such as an idea or a theory that is formed in people’s minds. He or she will compare it with the predicted results provided by his or her existing constructs when a person perceives something. If the two agree, the original construct will be strengthened, if the prediction is not consistent with the reality, then the original construct will be questioned and amended. The personal construct is not easily found, accordingly, Kelly designed a method to elicit it, repertory grid technique (RGT).

51.1.4 Objectives

The objective is to verify whether topological properties perception is applicable to product recognition. If the topological properties variation occurs in the shape of the product, the product will get much attention, and the product will have the opportunity to be aware of the innovation that cannot be felt by the vision, such as function and experience. Therefore, this study hypothesized that the perception of topological properties (holes, connectivity, and inside/outside) exists in the shapes of the products, and human can pay attention to the products that are relational to the variation of topological transformation occurred in the shapes.

The main research process is as follows:

Stage 1. We select the product as research object in terms of topological properties. In this study, we select bicycle as research object.
Stage 2. Choose the latest model from the existing brand bicycles, select the winning works from the top product design awards or bicycle design awards, and select the case from the blueprints of concept bicycle design. Compare the selected bicycles with the "standard bicycles". The first few cases of the most significant difference are taken as the research object.
Stage 3. The selected bicycles as the elements in RGT, elicit the constructs from these elements, and then the subjects rate the elements in terms of constructs. Finally, we interpret the results of operation.

In this study, bicycles were selected as the object of the experiment. There is the main reason that is the attributes of the product shape. The shape of a bicycle is approximately two-dimensional, namely, "planarization". The shape of the similar 2D product is more consistent with the object of topological perception, since the visual topological properties are based on two-dimensional manifold as mentioned before. We investigate a large number of bicycle designs and find that many innovations conform to the topology variation we have identified. Making a thought experiment on perceptual non-spoke wheel bicycle. The wheels in our impression are all with the spokes, and the spokes radiate out in the center of the hub. A person visually sees a spokes array as a disk compared with a non-spoke wheel and non-wheel can be seen as ring [6]. From the topology point of view, the disk and the ring are different topological properties. In general, the hub is located on the inner side of the rim and at its center. The hubs of some new transmission bicycles are still inside the rims, but at the edge, the other hubs are outside the rims, but are connected with the tire visually. Such changes also occur in the topology variation that is outside/inside. The seat, the handlebar, the chain rings, and wheels are connected through the frame. We can understand the frame as the connectivity part. The shape of the frame is visual performance of connectivity, and the change of the frame shows the connectivity variant of these parts. Through the above analysis, the bicycle has three kinds of visual topological properties.

Fig. 51.1 Standard bicycle

The so-called standard bicycle proposed in this paper is based on the concept and picture of bicycles given in the British encyclopedia, and select a closer bicycle as a reference object (Fig. 51.1).

51.2 Research Methods

51.2.1 Select Appropriate Elements

We choose the 30 bicycles from the latest model from the existing brand bicycles (e.g. Storck, Pinarello, and Nigolai), the winning works from the top product design awards or bicycle design awards (e.g. core77 Design Awards, and IBDC), and the case from the blueprints of concept bicycle design(e.g. Yanko Design, and Bicycle Design). We set the 30 bicycles as test bicycle. Among them, we selected especially four bicycles most consistent with the topological properties variation as the key test bicycles (Fig. 51.2). Each bicycle is displayed in black and white with a white background. At the same time, standard bicycle is placed in lower right corner of each picture. We arranged 30 persons to score the difference between the test bicycles and the standard bicycle in each picture. They are composed of college students, with an average age of 20 years and the same sex ratio. The score is 7 points, namely, the lowest difference is one, and the highest is seven. By K-means clustering based on the average of each bicycle, we got nine bicycles with the largest different degree and selected them as elements. The four key test bicycles were in the first nine ones (Fig. 51.3).

Fig. 51.2 Four key test bicycle

NO.1 NO.2 NO.3 NO.4 NO.5 NO.6 NO.7 NO.8 NO.9

Fig. 51.3 Nine largest different degree bicycles and their codes

51.2.2 Elicit Constructs from Elements

We use the RGT to find out how people distinguish the difference between the nine test bicycles and the standard one. The nine bicycles are displayed separately in black and white pictures with white background. The size of each picture is A4, so that the details of every part of the bicycle can be displayed as clearly as possible. We invited seven experts who were identified as high intake of bicycles as subjects. They come from product designer, mechanical teacher, product design professional teacher, product design graduate student, bicycle enthusiast. For the convenience of the subjects to choose the picture, then make nine numbered cards, which correspond to the numbers of the A4 pictures. The backside of the card is up; each subject selects three randomly each time and then divides the three pictures into two groups. The reasons for the subjects in the process of discrimination contain the concept of opposites, that is, the similarities between the paired elements, and the differences of the elements that are distinguished. The similarity—dissimilarity, the two pole attributes become a structure. Each subject elicited the constructs in about 60–80 min. The total of constructs show in supplementary material. According to statistics, the words related to seats were mentioned six times, and the words related to the frames were mentioned 13 times, six times referring to the chain rings or the transmission, the wheels mentioned eight times, and the whole of bicycles was mentioned 8 times. Therefore, we classify and summarize the five aspects of these constructs from whole, seat, frame, wheels, and chain rings, and finally summed up seven constructs [8]. Positive: Extraordinary, High-Tech, novel wheels, novel frame, novel seat, curiosity on the way of transmission, Try to ride. Negative: common, low-tech, common wheels, common frame, common seat, no curiosity on the way of transmission, do not want to try. All constructs do not directly use the terminology of visual topological properties, namely holes, connectivity, and inside/outside, but use elicitation words as constructs. The reason is that it is impossible for the subjects to understand the terminology of visual topological properties so that they cannot score in the next stage. Secondly, we learned about the description of the other five bicycles during the interview with experts and the bicycles are beautiful and avant-garde, and some of the bicycles are mainly curvilinear, dynamic, and strong. Most of the reasons for their attention are from the esthetic aspects of persons. If empty wheel and non-empty wheel is used directly as the construct, the construct is too obvious to refer to the key test bicycles, and the results have no help to the research. Therefore, the constructs of elicitation words are also suitable for the evaluation of esthetic. Under the guidance of elicitation words, subjects will intuitively express their focus on these bicycles. The key test bicycles are to show differences after RGT. The following are detailed explanations of the potential reference relation of these constructs and topological properties.

The purpose of the construct of Extraordinary–common is to refer to the hypothesis of this research as a whole; that is, topological properties exist in product shape. When the topological properties variant, people should be able to pay attention to this variation obviously. Topology variation occurs in product shape with novel structures and functions, and people are able to evaluate new structures and functions. This method realizes to evaluate the effect of topological properties. High-tech and low-tech are summed up from the whole body, just concerned about the sense of science and technology. Non-hubs, non-spokes, the circular chain ring and even is placed inside the rear wheel, and the suspended seats, all these representations give people a sense of high-tech. In order to explore even further the effects of topological properties on the subjects, the rest of the constructs refer to the topological properties of each part of the bicycle. The construct novel wheels–common wheels refers to holes and inside/outside. Novel frame-common frame and novel seat–common seat refer to connectivity. The function of the frame is to connect all parts of the bicycle together, the frame of standard bicycle is similar to the two triangles composed of diamond, and the shape is the most popular, it shows the most common connection about seat and handle, wheels and chain ring, seat and chain ring. The new frame shape subverts the conventional frame shape and creates a new connectivity between the various parts. The transmission construct refers to the hole and inside/outside, and the degree of curiosity of the transmission means the attention of the hole and the inside/outside. Whether or not to ride is direct to learn about the level of concern about bicycles with topological properties from the human mind. If people see more novelty products, they will naturally try to operate it. The impulsiveness of trying to ride is more from the novel transmission of the bicycle. This construction adds to the probability of removing the other five traditional transmission bicycles.

51.2.3 The Rating of Elements

Thirty other subjects rate all the elements according to the two poles of construct in the program. We used seven levels in the ratings. In dealing with the orientation of unrelated constructs, in this experiment, in order not to affect the operation of software, the practice was recorded as the intermediate value, that is, it was

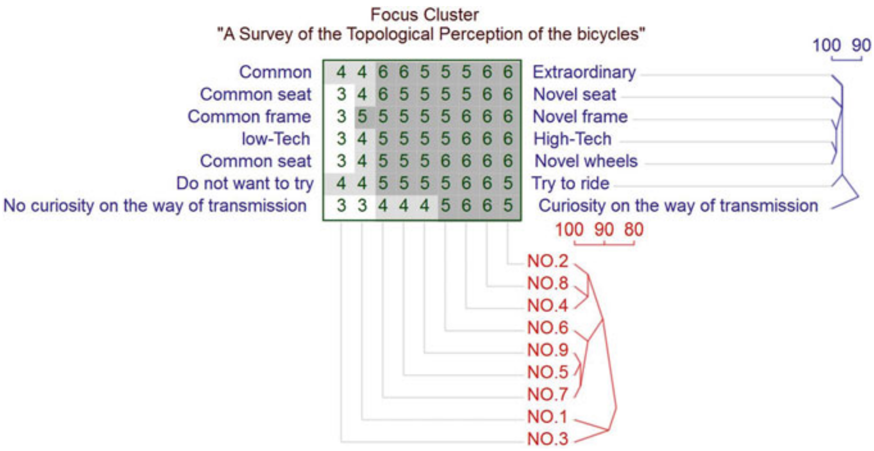

Fig. 51.4 Focus display

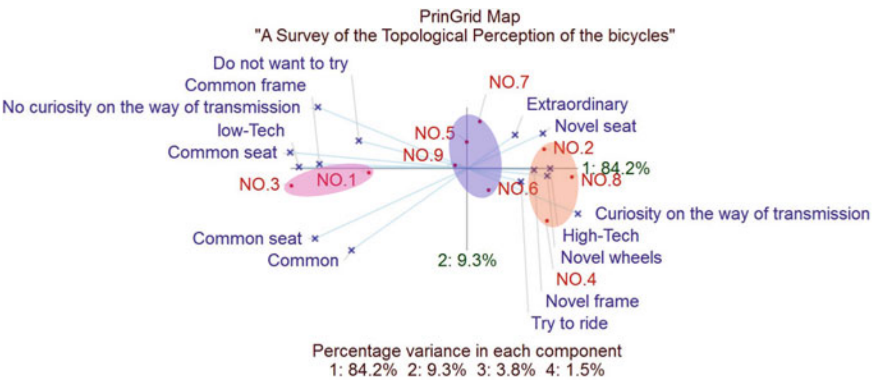

Fig. 51.5 Principal component analysis

recorded as four in the seven equal subscales. However, in the process of scoring, we try to let the subjects avoid making intermediate options. Using the free software web version, http://webgrid.uvic.ca. The resulting grid is displayed in Fig. 51.4 and Fig. 51.5.

51.3 Discussion

In the focus cluster display, elements and constructs are clustered according to the score. From the case of element clustering, the matching level of 90%, we can see that No.8 is the most prominent in the various constructions, followed by NO.4 and

No.2 in turn, No.6 is not good perform in the four key test bicycles and similar to No.9, No.5, No.7. From the perspective of constructs cluster analysis, the matching level of 96%, the transmission as a construct is the most significant difference for all constructs, followed by the Try to ride-Do not want to try and the sense of whole. The results of RGT of the four key test bicycles are explained below.

No.8 and No.4 are completely non-chain transmission, and the other seven elements, including No.2 and No.6, can be classified as chain drive. In addition, the wheels and the chain rings of No.8 and No.4 are complete ring, the rear wheel of No.8 is connected to the outer link with the chain ring, and the No.4 is the internal connection. Therefore, No.8 and No.4 are different only in the two constructs, extraordinary-common and novel seat–common seat. The No.8 performance is better than No.4 in the sense of whole, which is caused by the construct novel seat–common seat. The seat of No.8 is only connected to head tube and suspended. The seat of No.4 is connected to the rear wheel and head tube, respectively, and is in a stable state. The connection status between the seat and other parts is different in No.8 and No.4. The suspension state is more subversive to the experience of the stability of the seat, so it is more likely to arouse the curiosity in the ride.

No.2 and No. 8 are close to the whole shape, but the transmission of No.2 is actually a chain connection, and the hub is still kept in the rim. The hub of No.2 does not have topological characteristics variation, from inside to outside, and therefore is weaker than No.8 in the curiosity of the transmission.

The topological properties of No.6 are the weakest in the four key test bicycles. Only the front wheel is the property of the hole and without spokes in the rear wheel, and the other parts do not have the topological properties variation. The seat is still a direct connection with the rear wheel, head tube and chain rings, which is very similar to the seat structure of the standard bicycle.

In addition, we can also verify the existence of the topology properties of the four key test bicycles from the scores and cluster analysis of No.9, No.5, No.7, No.1, and No.3. They were beautiful and avant-garde, so they were able to enter the first nine most significant difference bicycles in the first test. In the course of interviews with experts, we learned that most of the reasons that they can attract person's attention are mostly from styling esthetics. In terms of their scores and cluster analysis, they do distinguish between the four key test bicycles. That is to say, these two kinds of bicycles (i.e., the four key test bicycles and the others) are the most attractive, but the reasons for attention are different, namely topological properties and esthetics. No.9 ranked first in the first experiment and No.6 with it in the same cluster when we select the matching level of 90%. The frame of No.9 also contains topological properties, at the same time, the topological properties of No.6 is the weakest in the four key test bicycles, therefore, this is the two bicycles why are not very significant in causing attention.

This experiment on the topological perception of product shape defined two pairs of relationships: the link between topological properties and bicycles shape and that between attention and the variant of the topological transformation. In the case of the first relationship, the wheels variant from the spokes to the non-spokes, from the hubs to the non-hubs, from the non-empty wheels to the empty wheels, from the discs to the rings. The connection between the seat, the chain ring, and the wheels varies with the variance of the frame. From the perspective of topology, bicycles appear "holes", variations in connectivity and variations between inside and outside. It is proved that the theory of topological properties perception is applicable to the cognition of product shape. The new transmission, new structure, and new user experience appear on bicycle when it makes a variation of topological properties. The new experience can be firstly perceived from the vision, and this is a process of attention. Combining the above two relations, the experimental object bicycles showed the innovation process that applying the visual topological perception method to analyze the topological variation of the shapes, and then to the development of a new user experience. This process is enlightening to the design of product shape. The topology variation makes a change the homeomorphism of the shapes, and the ability to identify the change is likely to be the innate ability of human visual perception. Product shape is not a homeomorphism comparing to the previous one, it is likely to be a new function, new technology, new materials, and other elements as an implicit support. At present, this paper only carries out visual perception experiment on topological properties in bicycles, which has some limitations. However, the traditional fan and Dyson bladeless fan is also an example of topological perception, and the bladeless fans are very popular among the consumers.

51.4 Conclusion

In the future research, we will gradually extend the topological perception principle to more product categories and tentatively combine the method of topological perception with the other product innovation methods positively. For example, product design often uses a language of keywords, but turning keywords into visual image is a complex process [12]. The keywords transform into visual images and combine visual topological properties may be able to meet design requirements and gain priority visual attention.

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Chapter 52
Motivation for Do-It-Yourself in Rural Base of the Pyramid Communities and the Changing Landscape

Prarthana Majumdar, Sharmistha Banerjee, Jan-Carel Diehl and J. M. L. van Engelen

Abstract *Making* is a creative experience of imagination and tinkering through which one finds resourcefulness in surrounding objects and materials. The propensity to *make* has been widely studied through Ryan and Deci's self-determination theory that sheds light on how makers are driven by *intrinsic* and *extrinsic* motivational factors. However, most of these studies have focused on do-it-yourself (DIY) movements that originated in the West such as the maker movement, the steampunk movement, and regenerative living. In this paper, we focus on the Base of the Pyramid (BoP) community from rural India and present a study that investigates into the motivational tendencies that catalyze DIY in such communities. We studied DIY practices in five BoP communities in rural India (Assam, a northeastern state of India) through contextual enquiry using semi-structured interviews. In the light of practice theory that considers *skills*, *images,* and *stuff* as the three components of a practice, we analyzed the motivational factors that give meaning to DIY in rural BoP communities. Furthermore, the observed inter-generational trend(s) showed how the linkages between these interconnected elements are changing over time and how new meaning might be required for DIY practices to sustain in such communities.

52.1 Introduction

> If we stop thinking of the poor as victims or as a burden and start recognizing them as resilient and creative entrepreneurs and value conscious consumers, a whole new world of opportunity will open up. —C. K. Prahalad (2006)

The Base of the Pyramid (BoP) is one of the fastest growing consumer segments. It is the poorest portion of the global population living with an annual income which is below a certain purchasing power parity threshold. Although some

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difference exists in the exact value setting for the same, many researchers have set this at $2 per day [2]. This group lacks the income to satisfy their basic needs and suffer from a lack of access to public services and, in many instances, suffer from exclusion in social, cultural, and political arenas [2, 3]. Since Prahalad and Hart showed that the traditional aid strategy does not effectively solve the problem of poverty and suggested a market-based approach [4, 5], companies started exploring BoP market in two different ways. The first approach was to explore the economic potential of the BoP [1, 6, 7], wherein many companies started making "frugal innovations": products designed specifically for such markets with reduced cost, complexity, and functionality [8, 9]. Others adopted "bite-down" strategies which aimed at increasing their consumption by selling products in smaller quantities [10]. Despite the seeming profitability of this sector, many scholars today question the long-term sustainability and the actual empowerment that such strategies bring [10, 11]. Cheap shampoo sachets, for instance, in reality increase the long-run cost of the product for the BoP and are a huge source of environmental pollution since the multi-layer packaging cannot be recycled [10]. Furthermore, mass-produced products from Western companies often overlook the norms and aspirations of BoP consumers and invasively replace indigenous designs and locally produced goods [12]. They also often fail to make a distinction between satisfying essential needs and offering non-essential goods [13].

The second approach, also called as the second generation of BoP strategies, sees BoP as business partners wherein they are to be empowered, enabled, and involved in the process of business co-invention and co-creation. An example in this category is FabIndia [14]. Another approach is to empower these communities to self-produce goods for their own consumption, also known as "prosumption" [15]. Much like the maker movement that is growing as an antithetic response to passive consumerism, these communities can be stimulated to use their local resources and to produce their own goods with socioculturally embedded modes of production [16, 17]. BoP communities often have a tradition of DIY prosumption practices that have either sustained as survival or have evolved as craftsmanship with locally available materials [18–20]. Many of these indigenous practices have traced their way into the western world for their eco-friendliness such as the use of reeds for making mats and leaves for making disposable plates [21, 22]. Yet, just as the rise in consumerism led to an alienation of people from labor in Western societies, BoP communities are also witnessing a gradual drift away from DIY practices despite their significance as heritage and their local rootedness [23, 24]. Preserving their existing DIY practices and introducing new ones would need a thorough understanding of the various factors which motivate the BoP for it and how it is transforming over time due to the current consumption–production systems. Hence, in this paper, we seek to investigate why people do DIY in rural BoP communities and how is such a practice transforming over time.

52.2 Theoretical Background

DIY, traditionally, has been seen as a practice of making products or constructing solutions for one's own consumption [25–27]. The local term for this concept from various countries is "Jugaad (India), Guanxi (China), Blatmir (Russia), Quan he (Vietnam), Ubuntu (South Africa), and Gambiarra (Brazil)" [27]. These practices revolve around innovative make-do products (systems) born out of poverty to economically solve basic problems with resources in the immediate surroundings. Rural BoP communities also have grassroot innovators: individuals working outside the realm of formal sector to bring contextualized, bottom-up solutions to local problems in agriculture, transport, payment systems, or education [20, 28, 29]. However, the author could not find significant literature on the prosumption practices of the rural BoP communities.

Several researchers have studied DIY behavior from a psychological point of view and differentiated motivational factors into *intrinsic* and *extrinsic* based on Ryan and Deci's self-determination theory [30–33]. Ryan and Deci (2000) categorized *Intrinsic* motivation as the behavioral drive resulting from something being inherently interesting or enjoyable and *Extrinsic* motivation as the drive resulting from separable outcome such as economic returns, recognition, and feedback. *Intrinsic* motivation has three components: *competence*, *autonomy,* and *relatedness*. These tendencies are expressed only under specific conditions catalyzed by external agents. The propensity to seek *competence* is highly visible among DIY communities. Each is in a pursuit for greater self-expression, inventive epiphanies or finer craftsmanship [25, 31, 34, 35]. However, *competence* has to be accompanied by *autonomy* or a sense of free will that one is doing something out of one's own interests and values, to motivate an individual. The identity-seeking DIY'er is essentially seeking *autonomy* in trying to establish coherence between himself and his surroundings [31, 32, 35]. The final component, *relatedness,* refers to the need people have to be valued by family, peers, and social circles. The feeling of connectedness to a group with a similar culture or goals can encourage people to work collaboratively and seek recognition from peers [30–32, 36]. *Intrinsic motivation* can further be divided into (a) *enjoyment* and (b) *obligation/community* based. Hackers, for instance, not only act as part of a group with the goal to make all software openware, but also operate under the *norm* that their own work should be open source [33].

In this research, we use self-determination theory to analyze the motivations for DIY in BoP communities. However, in order to understand how DIY subsists in these communities, we consider DIY as a practice: "an active integration of materials, meanings and forms of competence" [37]. A practice embodies three loosely structured groups of elements: *skills, images, and stuffs* (Fig. 52.1). *Skills* embody learned routines, know-how, and ways of doing and feeling. *Images* are socially shared meaning related to the practice that give reasons for engaging in it. *Stuff* embodies the physical aspects: the objects and tools along with the body of the maker [38]. These elements are interlinked and interact with each other to transform

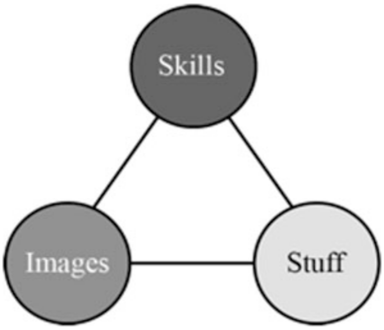

Fig. 52.1 Components of a practice [38]

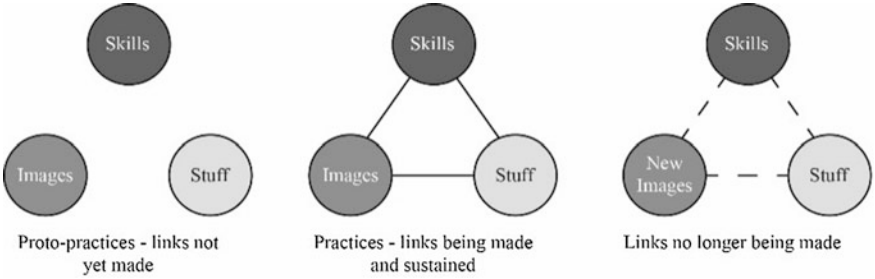

Fig. 52.2 Emergence, sustenance, and extinction of a practice [38]

the practice over time. For example, the coming of 3D printing (*stuff*) transformed the practice of prototyping and changed its image from a slow hands-on process to a fast automated process. It also implies a change in *skill* requirement, from skills in hand modeling to 3D modeling software. Establishing a practice often involves establishing these linkages to connect the *materiality* with the skills to execute and the reasons to engage in it. Similarly, the mutation of the linkages can deform the practice over time and eventually lead to its extinction through breakage of links (Fig. 52.2). (38) Practice theory has been used to analyze emergence, evolution, and extinction of practices [38, 39] and to design products with higher embeddedness in daily routines or to have higher sustainability [38, 40]. It provides us with a useful lens to examine DIY as a practice, the motivations that give it meaning and how such meanings are evolving over time.

52.3 Methodology

Research Questions: Our research had two primary questions: (a) What are the motivations that constitute *Images* for the practice of prosumption (DIY) in BoP communities? (b) How is this practice transforming over time?

Fig. 52.3 Research sites in India

Research Subjects: This study was conducted in five rural BoP communities, namely Joypur, Gopalpur, Paator Kusi, Sarthebari, and Naumati, in rural Assam in India (Fig. 52.3). People from each community had a different ethnic background except for Sarthebari and Naumati. The researcher visited nineteen low-income households in total. All the households sustained on agriculture. The women worked in the fields as seasonal labor. At times, they grew other crops such as betel nut, rubber, and bananas in their backyards and reared livestock. There were 31 respondents in this group (17 male and 14 female) from the age of 25 years to 70 years. We also interviewed fifteen young respondents (8 male and 7 female) from the age of 12–20 years. All of them either attended school or a community college.

Research Approach: We conducted a contextual enquiry in the aforementioned communities. We used fieldwork techniques such as touchstone tours in homes, field notes, pictures, and shadowing rural DIY'ers along with semi-structured interviews. We spent five days on an average in each village, from morning till evening in the fall season. Our foci during these observations were the kinds of *materials* and tools used and the *skills* involved in the practice. The semi-structured interviews focused on the *images (motivations)* of the DIY practice to the community and the individual. The interviews were transcribed and subjected to open coding. In order to glean *motivations* and *purposes* for doing DIY, we conducted a qualitative cause–effect analysis using the reference model construct from design research methodology [41]. The field notes and pictures were arranged under the themes (concepts) in order to aid in the development of the associated concepts. We also interviewed the young respondents with the same questionnaire to understand the *meaning* that they assigned to DIY so that we could identify if there was a variance or continuity in meaning. If we encountered a respondent who did not engage in DIY, we restructured the interview to study the kinds of activities that he/she was most *intrinsically* motivated for and what their major sense of purpose was. We, however, did not interview craftsmen as they were majorly driven by *extrinsic* motivation to do DIY.

52.4 Observations and Results

The touchstone tours around the houses revealed that rural people engaged in some form of *making* practice to be self-sufficient either in the form of weaving their own clothes, constructional DIY for making houses, sheds, and granaries or making quotidian products for transporting goods, and storage of food or for catching fish. Figures 52.4, 52.5 and 52.6 show a woman making a granary, a woven basket to transport fish, and a weaver working at her manual loom. A rich DIY tradition,

Fig. 52.4 A woman making a granary

Fig. 52.5 A woven basket to transport fish

nurturing a range of prosumption practices, was observed among the rural communities. They extensively used local materials such as cane, bamboo, various palms, coconut leaves and coir, woods (teak, sal, and gambare), water hyacinth, husk, hay, sand, cow dung, and silk cocoons (Eri and muga) and very basic tools such as knives, sickles, hammers, and shovels to more complex manually operated machines like looms (Fig. 52.6). Most of the DIY practices have evolved as a heritage for such communities, a means of fulfilling their material needs using local resources. The patterns of weaving, the designs of the products, and the techniques of making houses and granaries using mud, cow dung, straws, and bamboo were passed on from generation to generation. The respondents who engaged in DIY reported picking up such skills during the early years of their life. Fifteen out of the nineteen households also reported helping each other in heavy DIY activities such as construction or setting up of looms. Being part of a collectivist culture, the members valued cooperation and coordination to support each other in their survival needs. The women demonstrated a high sense of collectivism in their practice of weaving, wherein they shared ideas and designs with each other continuously.

Fig. 52.6 A woman weaving on a loom

In our efforts to understand the *motivations* and *purposes* to engage in DIY, we conducted a cause–effect analysis for each of the interviewees. Figure 52.7 presents the analyses of three representative subjects engaging in three widely conducted DIY activities. Being primarily a survival strategy, DIY in BoP communities is at times strongly driven by *extrinsic motivations* such as economic profit, lack of product availability, and need for customization of products. Recognition of work by peers and others in the community was also a strong motivator for DIY. The interviews, however, manifested several other intangible needs. They sought higher *competence* through creative expression and refinement of craftsmanship, higher *autonomy* by self-production of goods, and higher *relatedness* through sharing of ideas. The subjects also felt a sense of purpose in doing DIY. For some, it meant preserving traditions; for others, it was a way of bringing welfare to the community. Table 52.1 shows the major reasons and motivational factors which give meaning for the people to engage in DIY and the associated concepts that the interviews generated.

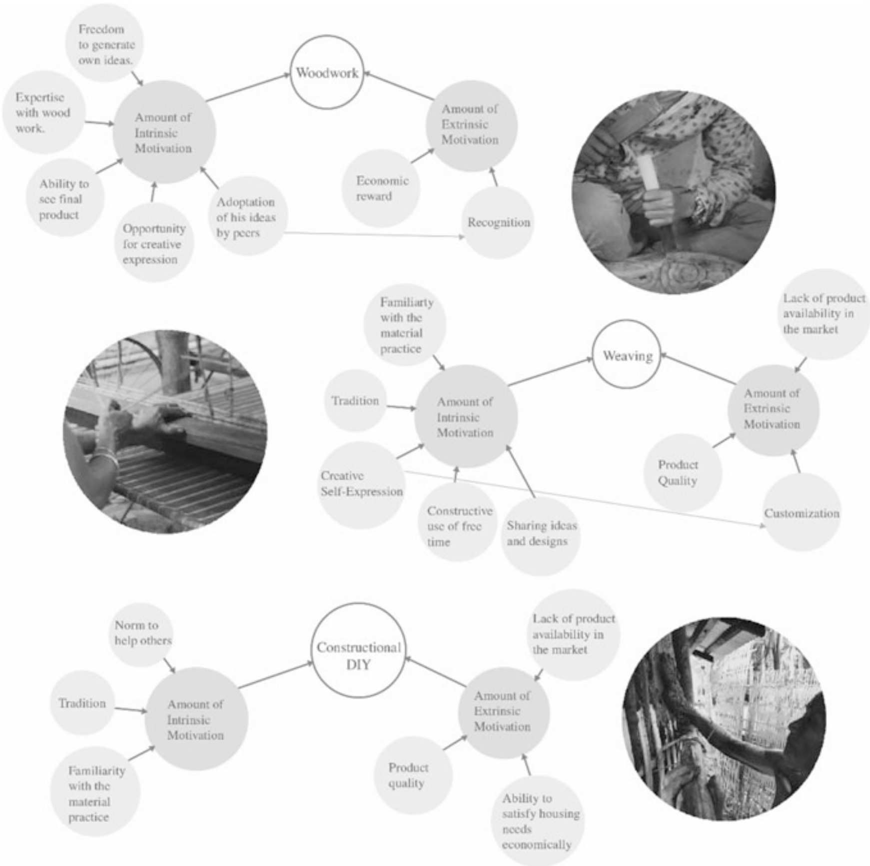

Fig. 52.7 Cause–effect analysis on three respondents of a few widely done DIY practices

The younger group of respondents, however, did not demonstrate a strong inclination toward doing DIY. Only one out of the eight male respondents reported doing technological DIY in the form of making small toys by repurposing parts from other gadgets. Three out of the seven female respondents expressed that they occasionally engaged in creative DIY projects such as making craft items or doing clay work. These young DIY'ers were at times, driven by a clear sense of purpose of achieving a goal through their work and at times, solely for the opportunity to dwell in their creative side. The respondents who did not engage in DIY did not perceive *making* as having the potential to make them feel higher *competence* and *autonomy* or even affording them the opportunity to fulfill their *relatedness needs*. In Fig. 52.8, we present a mind map depicting what the young respondents perceive as *competence, autonomy, relatedness,* and *purpose*: the meanings that were assigned to the DIY practice by the older respondents. Four out of the nine young male respondents actively engaged in sports to hone their athletic skills. It also gave

Table 52.1 Concepts and associated concepts derived from the interviews with opinions of subjects to exemplify

Concepts/Associated Concepts/Exemplary Opinion from a Subject		
Competence  Creative self-expression, ability to see final product, and growth in expertise. *"I like to work on challenging projects, where I can be creative in new ways."*	**Relatedness Needs** Sharing ideas and designs, and adoption of ideas by peers.  *"If I have a new pattern, I show it my neighbor and if she has one, she shows it to me."*	**Autonomy** Freedom to generate own ideas and ability to satisfy one's needs.  *"I make all small things that we use at home. We do not buy them from the market."*
Social norms Helping others in the community.  *"There is a norm in villages to help each other. If I run out of something, I can borrow it from the neighbor."*	**Extrinsic Motivations** Economic profit, recognition, product quality. Customization and lack of product availability in the market.  *"The government gave me a certificate for being a model farmer. They call me train others on farming techniques."*	**Purpose** Preserving tradition and community welfare.  *"I try to be of help to others. Being able to do community service is a privilege."*

them an opportunity to fraternize with friends and club members. The young female respondents viewed group activities in schools as their opportunity to connect with their peers and work collaboratively with them. Though all the respondents were from similar familial backgrounds and received similar education, the male respondents demonstrated a sense of purpose that was inspired by the problems that they witnessed in their community either in traditions, environmental problems, and deficiencies in education or political and sociocultural failings. The female respondents, however, expressed a greater proclivity for creative expression.

They experienced such activities as an immersion into a world of playing, tinkering, and creative imagining. We observe that while the older respondents viewed self-reliance and being connected to the community as their major source of motivation, the younger respondents opined, without exception, that only education and extracurricular activities can give them higher *competence* and *autonomy* for a stable future. The young respondents also demonstrated a clear divergence from their older generation in their sense of *purpose*. They had a higher awareness of global problems and how change was required on several fronts to uplift their community.

52.5 Discussion

DIY practices, in their ability to transform living for the poor by harnessing material resources from the environment, have become a part of tradition for these communities. Besides the *intrinsic* and *extrinsic* motivations, people often engage in DIY with abstract goals such as preserving traditions and ensuring community welfare. These motivational factors, reasons, and goals together constitute an intangible whole that gives a socially shared meaning to DIY practices for these communities. Our fieldwork revealed that prosumption practices have subsisted in such communities being supported by *skills* (know-how and expertise), *stuff* (tools and raw materials from the environment), and *images* (motivations, goals, and purpose). However, we also observed the links between the two elements: *Skills* and *stuffs* with *images* are decaying (Fig. 52.8). The new generation does not have the motivation to do DIY as their previous generation does. They do not perceive DIY as capable of affording them with either *competence* or *autonomy* to sustain themselves in the real context. Table 52.2 shows a comparison between the older generation and the younger generation on their perceptions of growing *competence, autonomy,* and *relatedness* and their sense of purpose. Free education has contributed to the movement of youth from hands-on activities to more academic pursuits in the hope of a better future [17]. The exposure to the world outside the vicinity of their villages, either through television or smartphones, has further given them a "vision of a good life" that is no longer aligned with the rustic lifestyle where self or social production of goods is a norm for survival.

Fig. 52.8 Mindmap showing what competence, autonomy, relatedness, and purpose means to the young respondents

Table 52.2 A comparison of what motivations and purpose is for the younger and older generations

	Competence	Autonomy	Relatedness	Purpose
Older generation	Creative self-expression, ability to see final product, and growth in expertise	Freedom to generate own ideas and ability to satisfy one's needs	Sharing ideas and designs and adoption of ideas by peers	Preserving tradition and community welfare
Younger generation	Academics, extracurricular activities, and moving out of the village	Academics and jobs	Sports, playing with friends, and group projects	Community work, bring change, discover other places, and reduce environmental pollution

	Competence	Autonomy	Relatedness	Purpose
Older generation	Creative self-expression, ability to see final product, and growth in expertise	Freedom to generate own ideas and ability to satisfy one's needs	Sharing ideas and designs and adoption of ideas by peers	Preserving tradition and community welfare
Younger generation	Academics, extracurricular activities, and moving out of the village	Academics and jobs	Sports, playing with friends, and group projects	Community work, bring change, discover other places, and reduce environmental pollution

52.6 Conclusion

This study studied the DIY practices in five rural Indian BoP communities. The researcher observed several prosumption practices that utilized local materials. The knowledge and skills have become embedded in such societies. However, such practices are morphing over time. The new generation today does not share the same motivation to do DIY as their previous generation. Affordable primary education, access to technology, and the availability of cheap consumer goods have altered the way people perceive DIY. Though the local materials are still available, these practices have lost their meaning (*images)* and the younger generation no longer finds a reason to learn such skills. Reviving such prosumption practices or designing DIY products would necessitate that we understand this changing landscape of motivations and meanings. For the practice to sustain in future, it must find new meaning.

52.7 Implications for Designers

The maker movement today has gained significant momentum in the West. FabLabs that started from MIT have been setup even in remote places of the world [42]. But when it comes to BoP communities that are only on the verge of being alienated from labor with the evolution of new survival norms, is it possible to make them adopt a DIY culture by simply providing them with a physical laboratory? Understanding the way in which they perceive *making* is crucial in designing an experience that makes them feel a growing sense of *competence*, *autonomy, relatedness,* and fulfillment of purpose. One way to retain prosumption practices in these communities is to introduce new DIY practices with new *skills* and *stuffs* that are aligned with the meaning that younger generations assign to DIY or to re-establish the link with traditional meanings of DIY by educating the youth about the sustainability aspect of such practices (Fig. 52.9).

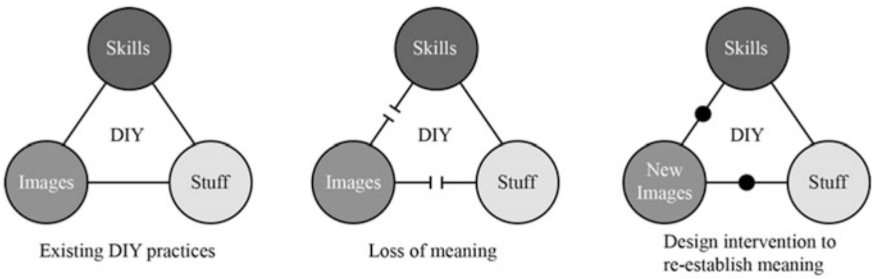

Fig. 52.9 Re-establishing linkage with new images to sustain DIY practices

52.8 Limitations of This Study

This study was conducted in the eastern part of India with rural BoP communities. The results of this study are socioculturally sensitive to this context. The meaning attached to DIY practices and inter-generational trends around these practices in other BoP communities might vary.

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Part VI
Design of/for User Interfaces, User Experience and Human Computer Interaction

Chapter 53
Design and Development of a Stencil for Mobile User Interface (UI) Design

Anirban Chowdhury

Abstract The paper prototyping is a quick method of UI design and concept presentation. However, hand-drawn UI prototypes (paper prototypes) are not always visually good. Sometimes rough hand sketched prototypes create confusions during UI concept validation with the target users or clients. Therefore, aim of this paper is to design and develop the UI stencil to help mobile UI designers to crate quick, easy and visually pleasing paper prototypes. A total of three UI stencil prototypes were designed and developed for usability testing to ensure the user acceptance of UI stencil. It was observed that UI designers were willing to use the 'Stencil-3' for mobile UI design as the level of perceived usability and perceived ease of use were higher in case of 'Stencil-3' than the other stencils. Moreover, it was observed that users were taken comparatively less time for UI screens using 'Stencil-3' than the time taken for hand drawings of the same UI screens. Hence, this UI stencil might be beneficial for UI designers for quick, consistent and pleasant paper prototype design.

53.1 Introduction

With the advancement of Information and Communication Technologies (ICT), there is tremendous increase in number of mobile users in India and abroad. Recently, 'Statista' have predicted the worldwide number of mobile phone users as 4.93 billion by 2018 and 5.07 billion by 2019 [1]. Therefore, there are lots of demand in the field of mobile apps design. Due to this huge demand in market, many User Experience (UX) and User Interface (UI) designers are working for UI design of mobile apps. Often, they go for paper prototyping as it is one of the fast and easy ways to design and refine user interfaces [2]. Currently, user interface (UI) designers create paper prototypes of mobile apps to present and test the UI

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concepts quickly with their clients or target users when they are co-located in the design studio [3]. Paper prototypes were used by interaction designers basically for two purposes—(1) concept validation and (2) requirement analysis for the software Graphical User Interface (GUI) design [3, 4]. However, there is software (e.g. Adobe XD, Balsamiq, and InVision) available in the market for UI designers to create a GUI in digital platform, still UI sketching is a quick method to represent UI concepts. Eventually, it is observed that rough UI sketches are not always visually pleasing. It might also be difficult for client or stakeholder to realize the design with hand sketched UI. Therefore, there is a need for a device which will help UI designers to make a quick and visually pleasing UI on paper. Literature suggests that visual appeal and UI quality influence purchase intention of the users [5, 6]. Hence, in this study, an attempt has been made to design a stencil for UI designers which will help them to draw visually delight mobile GUIs very easily and quickly.

It is well-established fact that a product is usable if this is easy to use and useful to the context of its use [7–9]. Hence, there is a chance of acceptance of proposed UI stencil if it is useful for mobile GUI design and if it is easy to use then there is a chance that users will use it. It is well established that usability of the product is positively correlated to product acceptance [10]. Therefore, this paper described a User-Centred Design (UCD) process to design stencils for UI of mobile phones and validate the stencil design with user feedbacks.

53.2 Methods

53.2.1 Preparation of Stencils

Initially, a total of 40 icons were selected from ‘Google Material Design Icon Library’ as per mobile app design (e.g. food delivery app), by a team of expert UI designers ($N = 5$, Age range = 25–35 years) with average experience of 5.5 years in IT industry. A total of 33 icons were shortlisted for UI stencil preparation based on the expert suggestions focused on the frequency of common icon usage during mobile GUI design. Experts also suggested to implement two different sized rounded rectangles, circles and lines for the UI stencil. A total of three different types of UI stencil prototypes (‘Stencil-1’, ‘Stencil-2’ and ‘Stencil-3’) with varied icon arrangement based of the frequency of usage (as suggested by experts) were made. The suggested icons, shapes and lines were implemented in those stencils. However, these three UI stencils had three different kinds of icon arrangements as shown in Fig. 53.1. All these GUI stencils were made up of 2 mm acrylic sheet and these were prepared through LASER cutting technique. Two different coloured (red and transparent) acrylic sheets were tried for different look and feel of UI stencils. The mobile UI stencils were designed such a way that UI designers might draw silhouette of a mobile screen as well as they could draw icons and other shapes on the screen of the paper prototype. Designers may draw UI screen of a size of 5.5 inches using these prepared stencils.

53.2.2 Participants

Initially, a total of 45 users were participated in this study for the UI stencils testing. This big user group was further subdivided into three user groups according to three different stencils. Each user group composed of 15 UI design students (age range: 19–26 years, M: 57%, F: 43%). Later, other 15 participants (user experience design students, age range: 22–26 years, M: 53%, F: 46%) were employed to compare UI design outcomes (usability wise best stencil-based UI drawing vs. hand-drawn UI drawing). All users were assigned randomly in this study.

53.2.3 Variables and Measurement Scales

A total of two dependent variables (perceived usefulness and perceived ease of use) were chosen to measure usability of the stencil and one dependent variable (willingness to use) for understanding the acceptance of the UI stencil. Dimensions of the perceived usefulness (PU) and perceived ease of use (PEoU) were adapted from Segars and Grover (1993) [9] and a seven-point Likert scales (where '1' means strongly disagree and '7' means strongly agree) were prepared as per the requirement of the study. Reliability of these two scales was tested using calculation of the value of Cronbach's alpha. The alpha value for both of these two scales was 0.96 which was more than the minimum requirement value 0.70 designated both of these scales are reliable [11]. The willingness to use (WU) is also measured using a self-developed seven-point Likert scale (where '1' means strongly disagree and '7' means strongly agree). The alpha value for this scale was 0.98 which signified the scale is reliable [11]. Please find items of all of these three scales in Table 53.1. The UI design outcomes were measured depending on time taken to draw three mobile UI screens (stencil-based UI drawing vs. hand-drawn UI drawing) and aesthetic quality of these drawings as articulated by UI designers.

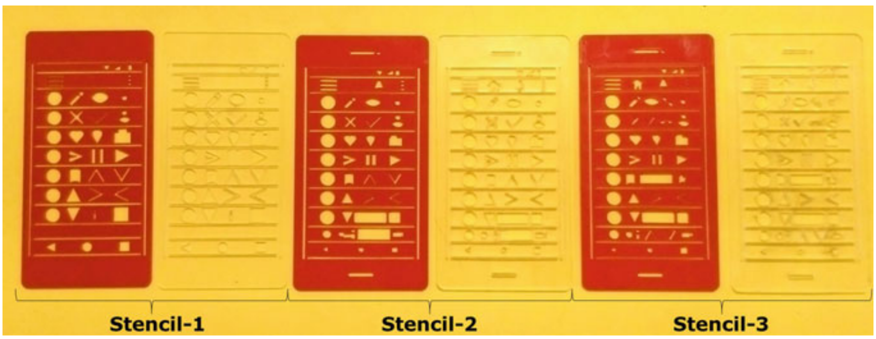


Fig. 53.1 The UI stencils considered under the current study

53.2.4 Procedure

In the first study, stencil prototypes were individually shown to aforesaid three user groups and all users were asked to draw 10 UI screens randomly for food delivery mobile app using a particular stencil ('Stencil-1' OR 'Stencil-2' OR 'Stencil-3') and eventually they developed paper prototypes. All users were asked to use the 0.5 pencil when they draw the UI screens, to control the effect of pencil graphite diameter on PU, PEoU and WU. Then, each user was asked to give their valuable feedbacks in a specified questionnaire. The PU, PEoU and WU of the stencils were measured on seven-point Likert scale. Immediately after this, user interviews were conducted to understand the mindset of users about usage of UI stencils when they had used UI stencil. The second study was conducted applying the best stencil among proposed stencils. In this phase, users were asked to see three pre-drawn UI screens (please find Fig. 53.2) about the plan of a food delivery app (the screen-1 was about the log in or sign up screen, screen-2 was for menu screen of the app and the screen-3 was made for job card) carefully. After that they asked to draw three same UI screens one using the best stencil identified in the first study and then the freehand sketch of these screens, as soon as possible.

A stopwatch was used to monitor the screen design time. Then, average time for completion of three UI screens for food delivery mobile app was compared (stencil-based UI drawing vs. hand-drawn UI drawing). Design students were allowed to use 0.5 pencil and rubber during UI screens the video recording was taken during the paper prototyping (stencil-based UI drawing vs. hand-drawn UI drawing) for observation of user behaviour using a video camera. Please find the experimental set-up for the videographic observational study in Fig. 53.3.

Table 53.1 Items of the relevant scales used in this study

Item no.	Scales for dependent variables
Perceived Usefulness (PU)	
PU1	The UI stencil makes the UI design job easier
PU2	The UI stencil is very useful for UI design as drawn UI quality is satisfactory
PU3	The UI stencil increases the productivity of UI design
Perceived Ease of Use (PEoU)	
PEoU1	The UI stencil is very easy to use
PEoU2	The use of the UI stencil is easy to learn
PEoU3	Using UI stencil, it is easy to become a skilful
Willingness to Use (WU)	
WU1	I am willing to use this stencil again in future for the UI design
WU2	I would love to reutilize this stencil for UI design
WU3	I desire to do more UI design work using this stencil

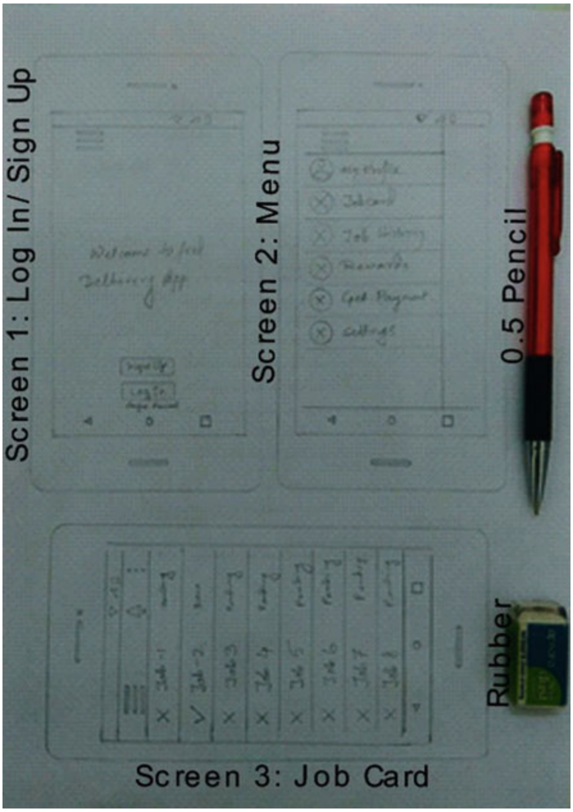


Fig. 53.2 Pre-drawn reference UI screens and tools used in the paper prototyping time evaluation study

Fig. 53.3 Experimental set-up for observational study

53.2.5 Statistical Analysis

As there were a less number of participants (only 15 users) in each group of the study, the obtained data series for the all variables were not following the normal distribution. Therefore, it was decided to conduct the Kruskal–Wallis test to compare the stencil types (three) wise mean differences in PU, PEoU and WU. Later, Mann–Whitney U test was conducted to for multiple comparisons ('Stencil-1' vs. 'Stencil-2', 'Stencil-2' vs. 'Stencil-3' and 'Stencil-1' vs. 'Stencil-3'). For comparison of UI screen drawing time (stencil-based UI drawing vs. hand-drawn UI drawing), the 'Wilcoxon Signed Rank Test' was conducted as it was a within subject study design.

53.3 Results

53.3.1 Questionnaire-Based Study

In the Kruskal–Wallis test, it was observed that mean values of PU [$\Sigma^2(2) = 34.731$, $p < 0.05$], PEoU [$\Sigma^2(2) = 37.529$, $p < 0.05$] and WU [$\Sigma^2(2) = 39.466$, $p < 0.05$] were significantly varied due to exposure of three different types of UI stencils to the user groups. Multiple comparison test (Mann–Whitney U test) revealed that 'Stencil-2' is significantly better than 'Stencil-1'[$Z_{\mathrm{PU}} = -4.306$, $Z_{\mathrm{PEoU}} = -4.214$, $Z_{\mathrm{WU}} = -4.722$] and 'Stencil-3' is significantly better than 'Stencil-1' [$Z_{\mathrm{PU}} = -3.944$, $Z_{\mathrm{PEoU}} = -4.733$, $Z_{\mathrm{WU}} = -4.709$] and 'Stencil-2' [$Z_{\mathrm{PU}} = -4.678$, $Z_{\mathrm{PEoU}} = -4.702$, $Z_{\mathrm{WU}} = -4.703$] as the mean values of PU, PEoU and WU were significantly higher ($p < 0.05$) in case of 'Stencil-3' than 'Stencil-1' and 'Stencil-2'. Please see stencil wise mean variations of PU, PEoU and WU in Fig. 53.4.

53.3.2 User Interview

Users (65%) said that '*Icons of the* '*Stencil-1*' *are not as per the frequency of their use*'. A total of 72% users said that '*few icons are not smoothly drawn on paper using the* '*Stencil-2*''. About 85% users were '*satisfied with icon arrangement and quality of drawing of icons using the* '*Stencil-3*' *as the designed screens using* '*Stencil-3*' *are better than hand drawn UIs*'. Hence, the 'Stencil-3' is more usable and acceptable than the 'Stencil-1' and the 'Stencil-2' among participated UI designers.

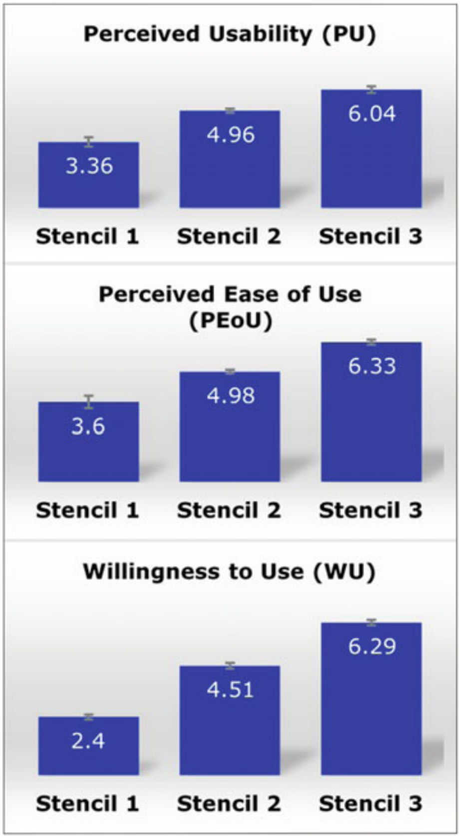


Fig. 53.4 Stencil type wise mean variations in perceive usefulness (PU), perceived ease of use (PEoU) and willingness to use (WU)

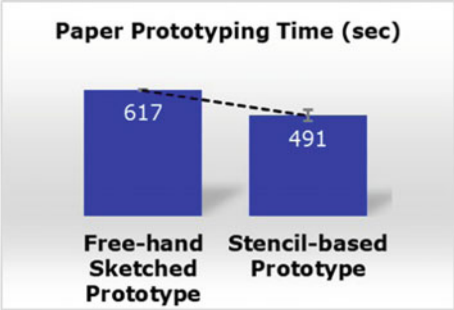
53.3.3 Paper Prototyping Time

There is a significant difference observed in case of average time taken for three UI screen drawing or paper prototyping of food delivery app ($Z = -3.011$; $p = 0.003$), between two conditions (stencil-based UI drawing vs. hand-drawn UI drawing). It took comparatively less time in case of stencil-based prototyping than the freehand-based drawing of UI screens (please see Fig. 53.5).

53.3.4 Observations from Videographic Data Analysis

All users were sucked with the tick symbol drawing while using 'Stencil-3'. Among them, many users (80%) have broken graphite-head of the pencil during tick symbol drawing. Users told—*the prototype drawing outcomes of stencil-based UI*

Fig. 53.5 Variations of paper prototyping time for food delivery app



drawings were better than the free hand sketched UI screens in terms of look and feel (86.7%). Around 93.3% participants articulated that the consistency of the screen size could be well maintained using ‘Stencil-3’.

53.4 Discussions and Conclusion

The UI designers found the ‘Stencil-3’ as better in terms of arrangement of icons and other design elements such as circles and lines, as ratings of PU and PEoU were high for ‘Stencil- 3’ in comparison with ‘Stencil-1’ and ‘Stencil-2’. User interview report suggested that most of the users were happy with UI screen design outcomes with ‘Stencil-3’. Most of the user rejected ‘Stencil-1’ as icon arrangements on stencil were not as per the frequency of use. Users refused to use ‘Stencil-2’ as icon shapes created hindrance in smooth drawings which leads to ugly UI screen design. Results of few studies also report the similar fact e.g. purchase intention of the users are less if there are low levels of visual appeal and UI quality [5, 6]. Therefore, these were the probable causes of getting high ratings for PU and PEoU in case of ‘Stencil-3’. Users reported usability is the more valuable predictor for product acceptance [10] and users will accept the product if perceived PU and PEoU are high [7–9]. Therefore, it can be concluded that UI designers might accept ‘Stencil-3’ for their UI design work. Results of WU also support the same fact as mean value of WU was significantly higher in Case of ‘Stencil-3’ than the ‘Stencil-1’ and ‘Stencil-2’. The stencil-based UI design took comparatively less time than the freehand drawing time of UI screens, which is a real advantage of the UI stencil. Another advantage is that the stencil-based drawings of UI screens are consistent in size looks better than the hand-drawn screens (please see Fig. 53.6). If screens look beautiful, client or users might find the stencil-based drawings of UI screens as good and usable [12, 13]. Norman also argued—‘It’s not enough to build products that function, understandable and usable, but it should also bring joy and

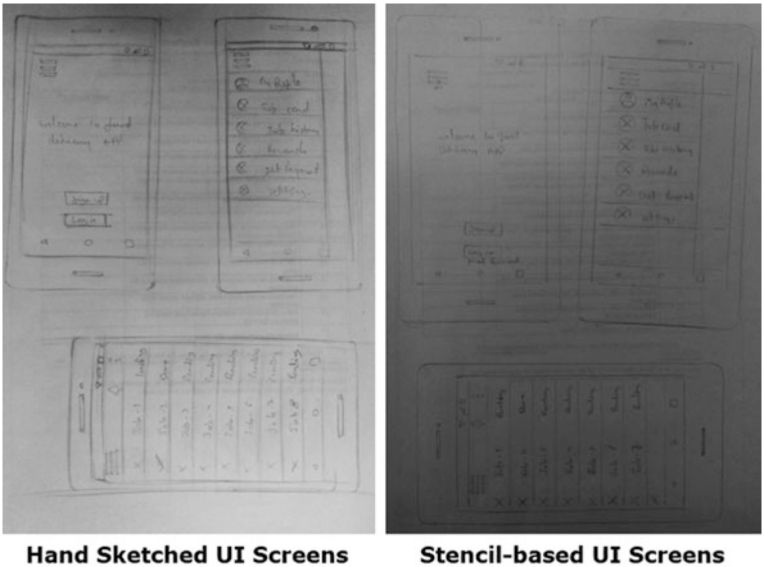


Fig. 53.6 Variations of quality of UI for food delivery app (freehand UI drawing vs. stencil-based UI drawings)

excitement, pleasure, fun, and beauty to people's lives' [14]. Therefore, the 'Stencil-3' might be acceptable by designers and clients up to certain extent, as long as the beauty of UI stencil-based screens are concern. However, tick symbol of the 'Stencil-3' was difficult to draw as observed in videographic study. Therefore, the size of the tick icon slot should be improved before final implementation and mass production of the 'Stencil-3'.

The current study is a preliminary study conducted on designers and limited to validation of made stencils by taking designers' feedbacks. Further validation of stencils is required as UI design outcomes using the stencil was not evaluated with clients or target users of the UI design in terms of conceptual understandability of the design. Paper prototypes might not be easily shared with clients seating at distant part of the world like Adobe XD, Invision etc., although it's possible to share these stencil-based UI screens as scanned copies or images via e-mail. Clients or target users, for certain mobile app, might not have the sketching skill. However, they might express and convey what's there in their mind about the UI design requirements easily by using the proposed stencil, during co-located design meeting. It is also reasonable to state that similar kind of stencils might also be useful for web-interface design, although the multimodal interface design features of the propose stencil are limited currently.

53.5 Practical Implications

The stencil evaluated in this study might be useful for UI designers for fast, easy and visually pleasing UI designs and paper prototype (low fidelity prototype) development. The interesting point is that the novice UI designers or target users or client who don't have good sketching skill might also draw UI screens using the proposed stencil. The user-centred design process adopted here in this study might be helpful for design and validation of similar kind of product, as aesthetics and usability are important for many tangible product developments [10, 14–18]. Scales used in this study might also be beneficial for UX designers to test the usability of the products.

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Chapter 54
Comparing Two Webcam-Based Eye Gaze Trackers for Users with Severe Speech and Motor Impairment

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Abstract This paper aims to develop and evaluate two different webcam-based gaze-controlled interfaces for users with severe speech and motor impairment (SSMI). We configured two webcam-based gaze trackers using open-source software (Python and JavaScript) and developed cursor control algorithm using the gaze tracker. We designed a quiz application to evaluate the webcam-based gaze trackers for both users with SSMI and their able-bodied counterparts. We also collected data using a commercial infrared-based eye gaze tracker. We noted that users with SSMI and able- bodied users could use the webcam-based gaze-controlled interface. It was found that for users with SSMI, speed of

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interaction was significantly faster for a low-cost infrared-based commercial gaze. Results from this study can be used to develop as well as select low-cost eye gaze trackers for users with SSMI. This might be the first study to evaluate webcam-based gaze trackers in a gaze-controlled interface for users with different range of abilities

54.1 Introduction

Eye gaze trackers are devices used to track eye gaze movements. Before digital computers, they were made of metal contact lenses. With advancement of computing technology, recent eye gaze trackers make use of computer vision algorithms to detect eye ball movement from digital image in real time and use that to predict points of fixation and saccadic gaze movement. Existing commercial eye gaze trackers mostly used infrared camera and bright or dark pupil technique [1]. The bright pupil technique allows image processor to locate centre of pupil. The eye gaze tracker can then locate where the person is looking on the screen based on the relative positions of the pupil centre and corneal reflection within the video image of the eye. However, there also exist eye gaze trackers that utilise cameras in visible spectrum like webcam or high-speed video cameras although those systems are either less accurate (for webcam) or costlier (for high-speed video cameras) than infrared trackers.

Traditionally, eye gaze trackers are used to record and analyse eye gaze movement for reading, visual search, Web browsing and similar tasks involving electronic or non-electronic displays. As eye gaze trackers became able to stream data in real time with negligible latency and same frequency of electronic displays, eye gaze trackers found application as a direct controller of graphical user interfaces. In a gaze-controlled interface, eye gaze movements were either used to facilitate another pointing modality by zooming in part of display or it is used to draw cursor on screen based on the points of eye gaze fixations. A detailed review of different gaze-controlled interfaces can be found in different papers [2].

Gaze-controlled interface found important application for people with different range of abilities where physical impairment impedes use of other input modalities like mouse, touchpad, touch screen or keyboard. There is already a plethora of commercial products [3, 4] available for electronic gaze-controlled interface. Most research for children with cerebral palsy was concentrated on developing applications like augmentative and alternative communication aid, menu structure [5–7], home automation application [8] and so on. Biswas [2] reported a detailed literature survey on state-of-the-art on gaze-controlled interfaces, and it may be noted that gaze-controlled interface require either bigger button size and arrangement [6, 7] or automatic zooming feature [9] or coupling with another interaction device [10] to accommodate inaccuracy in gaze tracking.

This paper proposes and compares two different webcam-based gaze trackers for a set of users with severe speech and motor impairment (SSMI) for an online quiz application. Commercial eye gaze trackers have the advantage of higher accuracy but those need to be separately bought and configured for individual computers. Webcam-based eye gaze trackers are far less accurate than infrared-based commercial ones, but if it is found useful even for a limited set of applications, those can be used without the need of buying or configuring any extra hardware.

In particular, we have compared performance of two gaze trackers both of which are platform independent and developed using open-source software. The first one uses landmark detectors through an OpenCV graphics library written in Python programming language, and the other one uses webgazer.js JavaScript software. We developed bespoke software to control a mouse pointer using eye gaze and an online quiz application with limited screen elements to compare performance of the gaze trackers. In the next section, we presented details on two gaze trackers. Initially, we collected data from able-bodied participants and then repeated the study with users with SSMI. We compared the number of participants able to use the system and reaction times of participants.

54.2 Related Work

Webcam-based gaze tracking is not a new concept [11] although deploying such a system for users with severe speech and motor impairment was not widely reported. Most webcam-based systems initially detect face using standard OpenCV library and then based on the relative position of pupil within the standard geometry of eyes estimate gaze position. However, none of these webcam-based trackers are evaluated as extensively as the commercial infrared-based gaze tracker. Khonglah and Khosla [12] reported an eye gaze tracker that uses Viola–Jones [13] detector to detect face and a blob detection algorithm to detect glint from the pupil. However, the system is only tested using a heat map on interfaces having only two targets. Cuong and Hoang's [14] system did not detect face, rather directly detect eyes and tested for only five positions (right, left, straight, up and down) on screen. Sewell and Komogortsev [15] used a feed-forward two-layer neural network to estimate gaze vectors from the images of eyes but already reported problem in extrapolation about training the network while detecting eye gaze for one of 50 random points on screen. The ITU gaze tracker [16] requires a special hardware to hold the webcam near the eyes, and it was evaluated for a typing application by able-bodied users and one motor-impaired user with ten targets on a projected screen. There are also a few commercial webcam-based gaze trackers (like Web gazer, https://webgazer.cs.brown.edu/ or xLabs gaze, https://xlabsgaze.com/) but they are mainly advertised for recoding browsing behaviour of Web users.

We noted from previous studies [17, 18] that that users with SSMI require a minimum size of screen elements, which reduces the density of screen elements. Additionally, with a nearest neighbourhood prediction algorithm, users need not to accurately place pointer on screen elements; the algorithm activates target nearest to the present pointer position. Hence, we can compromise the accuracy of eye gaze tracking. In the following subsections, we presented a low-cost eye gaze tracker that does not require any special hardware, rather can track eye gaze from standard webcam video feed.

54.3 Proposed Approach

54.3.1 First Implementation—Landmark Detection

Initially, we have used a Viola–Jones-type object detector [13] to detect face from the webcam image. After that, we extracted the eye regions from the facial image for further processing. From the face region, the eyes were extracted. We noted that a Viola–Jones-type detector [13] is precise but expensive in terms of computation time for detecting eye region. So, we used a quicker method based on the dimension of the face and relative position of eyes in the face as eyes are at certain fixed proportions to our face (Fig. 54.1). Once we extracted the eye region, we scaled it down to smaller size to increase computation speed. For every video frame, the eye landmarks were detected and subsequently used to measure the eye aspect ratio (EAR) between the height and width of the eye.

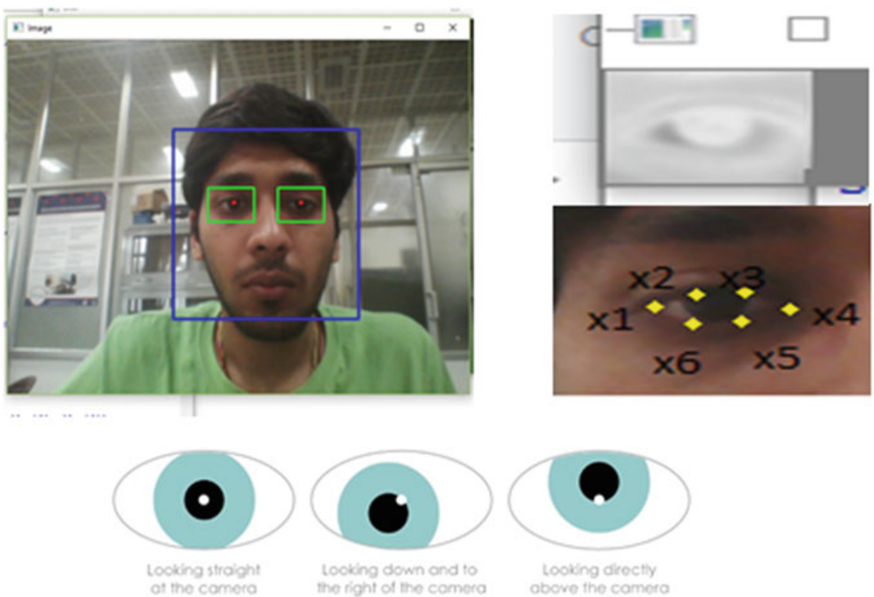

Fig. 54.1 Detecting eye gaze from webcam

$$\mathrm{EAR} = \frac{\|x2 - x6\| + \|x3 - x5\|}{2 * \|x1 - x4\|}$$

The 2D landmarks are depicted $x1 \ldots x6$ in Fig. 54.1. It may be noted that EAR remains constant irrespective of the distance between the user and the camera module. With the knowledge of the EAR and displacement of the pupil centre from the reference point, we predicted the nine directions of the gaze (top left, top middle, top right, left, centre, right, bottom left, bottom middle and bottom right). To detect the pupil position, initially we applied a threshold value on the image matrix representing the eye region based on the maximum value, and remove all the remaining values that are connected to the image borders and then find out the maximum value from the remaining set of values. We selected the pupil centre having the highest summation value of their neighbouring pixels.

A linear transformation function has been used to map the EAR and the displacement value of the iris form the centre to screen coordinates. The eye gaze was estimated by calculating mode from a number of EAR values measured in continuous frames. More details on this implementation are described in a different paper [19].

54.3.2 Second Implementation—Using Webgazer.Js

We have used an eye tracking library written entirely in JavaScript, i.e. webgazer.js (https://webgazer.cs.brown.edu/), that uses common webcams to infer the eye gaze locations of users on a web page in real time. WebGazer is an online eye tracker that uses common webcams already present in laptops to infer the eye gaze locations of Web visitors on a page in real time. The eye tracking model self-calibrates by watching users interacts with web page and trains a mapping between features of the eye and positions on the screen. It has two key components, a pupil detector that can be combined with any eye detection library, and a gaze estimator using regression analysis informed by user interactions. WebGazer technology is compatible with three open-source eye detection libraries for locating the bounding box of user's eye. The eye detectors that are evaluated in WebGazer are clmtracker, js-objectdetect and tracking.js. It can also be generalized to include others. There are two gaze estimation methods in WebGazer, one which detects the pupil and uses its location to linearly estimate a gaze coordinate on the screen, and a second which treats the eye as a multi-dimensional feature vector and uses regularized linear regression combined with user interactions. As the number of gaze locations we were getting in a particular time period through webgazer.js was high, so we had taken the mean of last eight points from webgazer.js for better target prediction and accuracy of system. Using the mean value of gaze location for last eight points, we have designed the following algorithm to select five screen locations on a web page through the webcam and webgazer.js.

54.3.3 Controlling Pointer with Inaccurate Eye Gaze Tracker

Both of the proposed eye gaze trackers were not as accurate as compared to commercial eye trackers. We have developed an algorithm to control a graphical user interface through inaccurate eye tracker. Box 1 shows the algorithm to activate one of five elements in a screen using eye gaze. In Algorithm 1, w and h represent the inner width and inner height of a window of a browser. We have taken five points on the screen by initializing appropriate values for dx and dy. The algorithm tracks the nearest screen element from the current gaze position. If the nearest screen element remains same for a particular time interval (dwell time), that element is selected. The duration of dwell time was configurable and set to 1.5 s by default.

Algorithm 1: Controlling the Gaze Point for a screen with five element

function TargetSelection (X, Y);
Input : Mean Prediction of last eight gaze locations as X and Y
Output: Selection of a particular screen element
Initialize dx and dy // We initialized $dx = 300$ and $dy = 200$
$points = [(x : dx, y : dy), (x : w - dx, y : dy), (x : dx, y : h - dy), (x : w - dx, y : h - dy), (x : w/2, y : h/2)]$
Calculate Euler Distance with each points
n = minimum(Euler Distances Point)
if *Minimum Point is n for dwell time* **then**
    Select corresponding screen element
else
    Again start from next minimum point
end

54.3.4 Application Used to Evaluate Gaze Trackers

We have evaluated the webcam-based gaze tracker for a representative application involving children with severe speech and motor impairment due to cerebral palsy. As the webcam-based gaze tracker had limited accuracy, we designed an online quiz application that had only four screen elements at any point. The quiz application displayed a question in middle of the screen, and the four options were rendered as pictures at the four corners of the screen (Fig. 54.2). The questions were

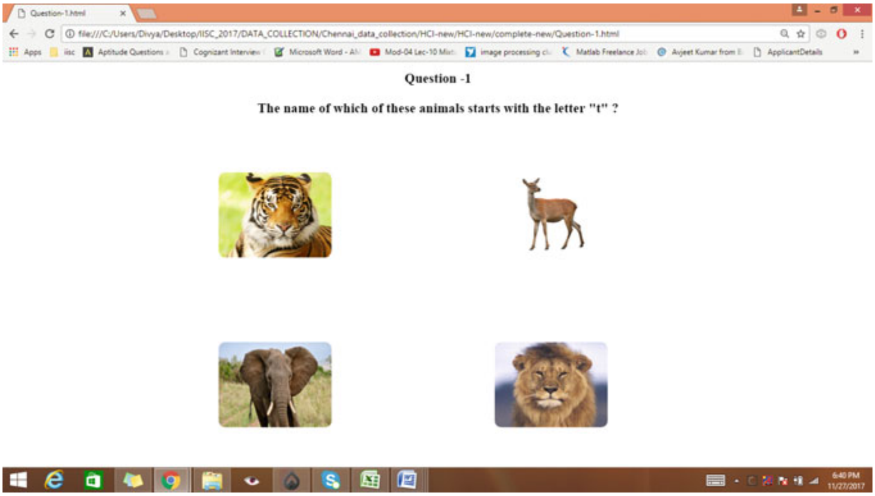

Fig. 54.2 Screenshot of quiz application

designed as simple and interesting for our end-users, who were teenage students. To compare performance of the webcam-based gaze tracker, we also collected data using a low-cost commercial infrared-based gaze tracker. As control group, we also collected data from able-bodied users using the webcam-based gaze tracker with the online quiz application. The following subsections furnished details on the study.

54.4 User Studies

Initially, we evaluated both gaze trackers for able-bodied users and subsequently for users with SSMI.

54.4.1 Study with Able-Bodied Users

Participants: We collected data from seven participants (five males, two females, average age 26.3 years). They have 6/6 corrected vision and do not have any cognitive and motor impairment. All participants were recruited from our university.

Material: The user trial was conducted using a HP Spectre laptop with Intel i7 core processor, 8 GB RAM and running Microsoft Windows 10 operating system. The laptop has a HP TrueVision HD 1.3 MP webcam, which was used to estimate gaze direction.

Design: The trial consisted of two conditions:

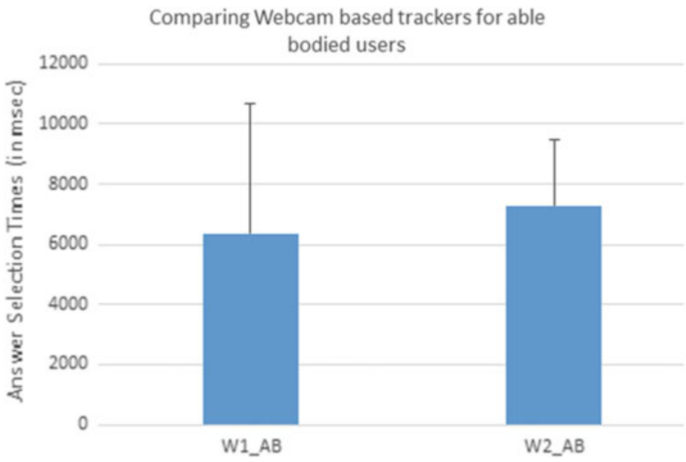

Fig. 54.3 Comparing answer selection times by able-bodied users

1. Using landmark-based webcam-based gaze tracker
2. Using webgazer.js-based webcam-based gaze tracker.

For all trial conditions, we used the online quiz application discussed before. The application consisted of ten multiple choice questions, each question had four answer choices and only one was correct answer. All participants practised the software before undertaking the trial. We also pointed the correct answer during the trial. We recorded timestamps of selection of answers. Order of conditions was randomized to minimize practice or learning effect.

Results: We calculated the answer selection times for each question for all participants. The average answer selection times were statistically significantly lower for the landmark-based gaze tracker compared to the webgazer.js library [$U = 1303$, $z = 3.04$, $p < 0.01$, Fig. 54.3].

As all users could undertake trials using both implementations, we went forward to collect data from users with SSMI, as described in the next section.

54.4.2 User Study with Children with SSMI

In this study, we compared the two different implementations of the webcam-based eye gaze tracker. We also included a low-cost commercial eye gaze tracker for comparing performance of the webcam-based gaze tracker.

Participants: We collected data from 11 participants (seven males, four females, average age 17.2 years). Our participants were quadriplegic due to cerebral palsy and were keen to learn operating computer. The participants were secondary students at *The Spastic Society of India* in Chennai. All trials and interactions with them were undertaken under observation by their care takers and school instructors. All necessary permissions were taken before undertaking user trials. We took help from their teachers, who are rehabilitation experts, to evaluate their physical conditions. According to Gross Motor Function Classification system (GMFCS), they were all at level 5 as they could not move without wheelchair. According to Manual Ability Classification System (MACS), some of them were at level 4 and rest were at level 5. A few of them could manage to move their hand to point to a non-electronic communication chart and others only relied on eye pointing. According to Communication Function Classification System (CFCS), all of them were at level 5 as they could not speak, could make only non-speech sound and communicate only through non-electronic communication board. They did not have access to any commercially available scanning software. Initially, we tried to use a mouse, joystick, trackball and stylus, but they could not manage to undertake any pointing and selection task using any of those devices as they could not make any precise movement using their hands necessary to control those devices. Their teachers and parents informed us that they were accustomed to use eye pointing with non-electronic communication chart.

Material: The webcam-based trial was conducted using a HP Spectre laptop with Intel i7 core processor and running Microsoft Windows 7 operating system. The laptop has a HP TrueVision HD 1.3 MP webcam, which was used to estimate gaze direction. For commercial eye tracker-based condition, we used an Intel NUC computer with dual-core i5 processor and Tobii eyeX gaze tracker [20]. The cursor control algorithm using the Tobii tracker is discussed in a different paper [17]. The display was rendered in an 18" screen.

Design: The trial consisted of three conditions:

1. Using landmark-based webcam-based gaze tracker
2. Using webgazer.js-based webcam-based gaze tracker
3. Using a commercial low-cost eye gaze tracker.

For all trial conditions, we used the online quiz application discussed before. The application consisted of ten multiple choice questions; each question had four answer choices, and only one was correct answer. All participants practised the software before undertaking the trial. We also pointed the correct answer during the trial. We recorded timestamps of selection of answers. Order of conditions was randomized to minimize practice or learning effect. We maintained same distance from camera for all participants, and trials were conducted in a well-lit room with lighting level between 300 and 350 lx.

Results: The average answer selection times in the commercial eye gaze tracker were nearly one-third that of the webcam-based gaze trackers and were significantly lower than both webcam-based trackers. We did not find any significant difference between the two webcam-based gaze trackers for users with SSMI (Fig. 54.4).

It may be noted that for four users, we needed to increase the dwell time of selection from its default value of 1.5 s. For three users, it was set to 2 s and for one

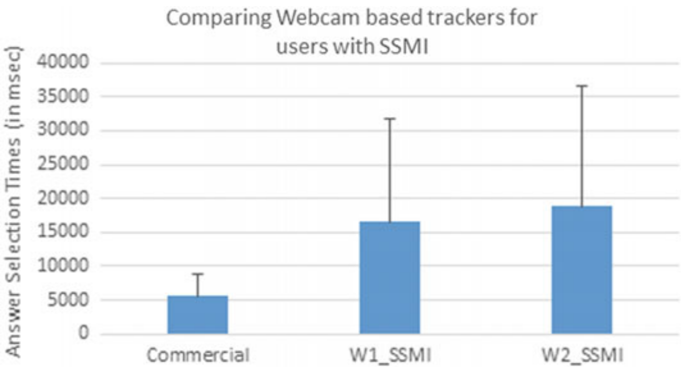

Fig. 54.4 Comparing answer selection times by users with SSMI

it was 3 s. The adjustment was done during the training stage and before start of the actual trial. However, for the commercial gaze tracker, all users could undertake pointing and selection tasks with a dwell time of 500 ms.

Discussion: This study shows that the webcam-based gaze tracker is not yet easily usable by all users with SSMI and the gaze detection algorithm is significantly slower than low-cost commercial gaze tracker. As the screen had only four selectable screen elements, accuracy of the gaze tracker was not the only issue. The latency in processing image and estimate gaze direction increased the pointing times for the webcam-based trackers. Additionally, users needed longer dwell time to select target in webcam-based system compared to the commercial gaze tracker. A follow-up study using a commercial gaze tracker involved users just to fixate gaze at a point on screen and recorded their gaze positions while they were trying to fixate attention [17]. Our study found that users with SSMI could fixate attention although have more uncontrolled saccadic gaze movements than their able-bodied counterparts. The offset did not correlate with screen position or angular deviation of the stimuli. The uncontrolled saccadic movement makes it difficult for webcam-based image processing algorithms to accurately estimate gaze position in a short duration.

Commercial infrared-based eye gaze trackers implement the gaze estimation algorithm in a dedicated circuit resulting less latency in image processing than a shared hardware circuit of a laptop with other programs running on it. Previous studies [17, 18] already indicated presence of nystagmus in people with cerebral palsy, and this nystagmus further increased latency in gaze estimation in webcam-based gaze tracker. Our study indicates that for users with SSMI, a commercial gaze tracker should be preferred over webcam-based ones for making gaze-controlled interface. Webcam-based gaze trackers can be considered to combine with other assistive modalities like single-switch scanning system to increase speed of interaction of the scanning system [21]. However, it may also be noted that the landmark-based gaze tracker worked faster than the webgazer. js-based implementation for able-bodied users, and the average response time was about 6 s. Webcam-based gaze trackers may be a useful alternative input modality for applications, where speed of processing is not a main issue and operators' hands are occupied with different tasks impeding them using traditional touch screen. For example, webcam-based gaze trackers can be considered for operating an electronic display in machines like computer numerical control (CNC) routers. It may be worthy to train webcam-based tracker using supervised machine learning algorithm to quickly detect eye region and run the software on dedicated graphics processing unit (GPU) to reduce latency.

54.5 Conclusion

This paper presents two different systems on developing and configuring a webcam for eye gaze tracking and then used the webcam-based gaze trackers in a gaze-controlled interface for users with severe speech and motor impairment (SSMI). As part of the study, we also implemented an online quiz application with only four screen elements. Our study shows able-bodied users could use the webcam-based gaze tracker to operate the quiz applications, but users with SSMI can operate the system significantly faster with a low-cost infrared-based commercial eye gaze tracker.

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Chapter 55
A Dimensional Analysis Across India to Study How National Cultural Diversity Affects Website Designs

Surbhi Pratap and Jyoti Kumar

Abstract Role of culture in design of artifacts is a well-recognized concept in literature. Several attempts to measure cultural differences at behavioral and artifactual levels have been reported. Isolated attempts to relate differences in designs to cultural differences have also been discussed both in the context of interaction design and other artifacts. However, most of the studies on influence of cultural differences on designed interactions have been focused on national cultures. This paper reports identification of different cultural zones within India, a country known for its cultural diversity and then relates the differences found in websites of those zones with the findings. Three zones within India were identified based on the literature and total of 340 participants from the identified zones were surveyed using the Value Survey Module 2013. The findings were correlated with total of 12-zone specific websites. The results showed that within India as a national culture there are distinct subcultural zones and they are significantly represented in design elements of interactive websites. Findings of this study can be used by interaction design community to develop culturally sensitive websites and develop better user experiences for localized design services within India.

55.1 Introduction

In today's era of internet ubiquity, it has become possible for information to be exchanged without geographical and temporal limitations [1]. However, the way this information is received depends on several factors like receivers' opinions, beliefs, and cultural perspectives [2]. This has led to an attribution of importance to the concept of culture in design of interactive systems [3, 4]. When leveraged by theoretic foundations in anthropology, semiotics, and design, culture has good

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potential for epistemic influences [5]. Works of Hofstede, Bond, Schwartz etc., have often been cited in the literature for their different approaches to understanding culture [6]. Most of these studies have considered nations as units of cultural representation. Several critiques of these studies are also available in the literature which argues that the concept of national culture may be problematic [7]. This paper has argued for the need to look at cultural diversity within a nation. This study started with the hypothesis that there may be cultural differences within nations like India that can be isolated using the same tools that prior research had presented for identifying national culture dimensions. For this purpose, this paper has used the tool developed by Hofstede [24] to conduct survey with 312 participants from three identified regions within India and found that significant differences were observed among them. Finally, a user interface analysis of local food ordering websites from each identified region was done and the results suggest that these subcultural differences have an effect on user interfaces of websites.

55.2 Literature Review

55.2.1 Culture and the Concept of 'National Culture'

Culture has been defined as a complex whole acquired by members of a society which includes knowledge, beliefs, arts, laws, morals, customs, and other capabilities and habits [8]. Researchers have proposed categories to analyze this phenomenon of culture in order to operationalize and measure it [9–11]. There are several studies that have proposed dimensions to a culture like Hall's theory of mono-chronic or poly-chronic, high- or low-context cultures [10, 12, 13]; Kluckhohn's five dimensions of attitude to problems, time, nature, form of activity, and reaction to compatriots [14, 15]; Hofstede's 6D model of power distance, collectivism versus individualism, feminity versus masculinity, uncertainty avoidance, indulgence versus restraint, and long-term versus short-term orientation [16]; Trompenaars's seven dimensions of universalist versus particularistic, individualist versus collectivist, specific versus diffuse, achievement oriented vs ascriptive, and neutral versus affective [17]. A majority of these studies, including the ongoing World Values Survey (www.worldvaluessurvey.org) are based on identifying common cultural values at a national level [18–20].

55.2.2 Hofstede's Cultural Dimensions in UX Design

In the field of UI/UX (User interface/User experience) design, Hofstede's culture dimensional analysis has been widely used. There are two reasons reported for this: one is that his cultural dimensions can be linked tangibly to user interface preference [21] and second that it is an empirical study done on a very large scale [22]. Hofstede's theory of cultural dimensions was proposed by using factor analysis to examine the results of a worldwide survey of employee values by IBM in the 1960s and 1970s. The original theory proposed four dimensions along which cultural values could be analyzed: individualism–collectivism; uncertainty avoidance; power distance (strength of social hierarchy); and Masculinity–Femininity (task orientation versus person orientation). Independent research later added two more dimensions—long-term orientation and indulgence. These cultural constructs were validated through establishing the significance of their correlations with geographic, economic, and social indicators. The dimensions have been extensively invoked by researchers to explain cross-cultural differences [6].

55.2.3 Critiques on Hofstede's 'National' Culture Dimensions

There have been various critiques of Hofstede's 6D model and one of the points of contention has been that Hofstede's study supposes cultures to exist at national level, whereas the phenomenon of 'nation states' itself is fairly recent [7, 23]. Hofstede himself has acknowledged that within nations there are other cultures, what he calls' subcultures' [16], but there is a limited research done on their influence on user preferences. While there have been few subcultural studies within the USA and China [21], there is very little literature available for countries like India. This research article addresses this gap by using the Value Survey Module 2013 to identify whether there are cultural differences within India and reports its influence on user preferences in the context of websites.

55.2.4 The Value Survey Module 2013

The Values Survey Module 2013 (VSM 2013) is a 30-item questionnaire developed by Hofstede and Minkov for comparing culturally influenced values of similar respondents from two or more countries, or sometimes regions within countries. It allows scores to be computed on six dimensions of culture, on the basis of four questions per dimension: thus, it counts $6 \times 4 = 24$ content questions. The other six questions ask for demographic information. The VSM 2013 manual advises that comparisons should be based on matched samples of respondents since other characteristics like gender, age, level of education, occupation, and kind of work might influence their responses [24]. For the present study, the values of individuals of similar gender, age group, level of education, and occupation are compared at the regional level within India.

55.3 Research Methodology and Observations

The study was conducted in three steps. In the first step, a literature review of anthropological and social classifications of India into regions based on race, geographical regions, and languages spoken was done to identify culturally distinct regions within India. This is presented in Sect. 3.1 titled '*Identification of culturally distinct regions within India*'. Next, a survey was conducted on 340 respondents from the identified regions who belonged to similar age group, level of education, and occupation using VSM 2013. Survey data was analyzed to deduce subcultural dimensions of power distance (PD), long-term orientation (LTO), uncertainty avoidance (UA), masculinity (MAS), individuality (IDV), and indulgence (IND). The survey design and its findings are presented in Sect. 3.2 called '*Deduction of dimensions of culturally distinct regions within India*'. In third and final step, content analysis was done on twelve locally popular food ordering websites from the identified regions to study the influence of subcultural difference on user interfaces of websites. The study and findings are presented in Sect. 3.3 titled '*Study of the influence of subcultural difference on website designs*'.

55.3.1 Identification of Culturally Distinct Regions Within India

Anthropologists have over the years classified India into regional groups on the basis of race, place of origin, languages spoken, physical characteristics, etc. [25, 26]. For the present study, identification of culturally distinct regions within India was done in two steps. In the first step, a literature review of existing regional classifications of India was done. For comparative study, a table has been prepared that exhibits major anthropological works which classify India into sub-categories (Table 55.1).

Table 55.1 Major classifications of India in anthropological literature

Sir H.H. Risley (1915)	1. Dravidian 2. Indo-Aryan 3. Mongoloid 4. Aryo-Dravidian 5. Mongolo-Dravidian 6. Scytho-Dravidian 7. Turko-Iranian

(continued)

Table 55.1 (continued)

Giufrida-Ruggeri (1921)	1. Negrito 2. Pre-Dravidian or Australoid Vedic 3. Dravidian 4. Tall dolichocephalic element 5. Dolichocephalic Aryan 6. Brachycephalic leucoderm
A.C. Haddon (1924)	1. The Himalayan region: Indo-Aryan, Mongoloid 2. The Northern plains or Hindustan region 3. The Deccan region or Southern plateau: Negrito, Pre-Dravidian, Dravidian, Southern Brachycephals, Western Brachycephals
Eickstedt (1934)	1. Weddid or Ancient Indians: Gondid, Malid 2. Melanid or Black Indians: South Melanid, Kolid 3. Indid or New Indians: Gracile Indid, North Indid 4. Palae-Mongoloid
B.S. Guha (1937)	1. The Negrito 2. The Proto-Australoid 3. The Mongoloid: Palae-Mongoloid, Tibeto-Mongoloid 4. The Mediterranean: Palae-Mediterranean, Mediterranean, Oriental 5. The Western Brachycephals: Alpinoid, Armenoid, Dinaric 6. The Nordics
S.S. Sarkar (1961)	1. The Dolichocephals 2. Australoid, Indo-Aryan, Mundari-Speakers 3. The Mesocephals: Irano-Scythian 4. The Brachycephals 5. Far Eastern, Mongolian
Malhotra (1978)	1. Negrito 2. Australoids 3. Caucasoids 4. Mongoloids
Mourant (1983)	1. Australoid type tribals 2. Caucasoids—slender and dark (South), robust and pale (North) 3. Mongoloids of the Himalayas

The classification proposed by Sarkar [26] is one of the most cited classifications and also Sarkar's classification conveniently maps onto the existing racial and linguistic groupings of India. This method of classification was found useful for the present study as it helps to look at website designs from the present sociopolitical groupings as well. In the next step, the detailed characteristics pertaining to each region in the regional classifications reported by Sarkar was mapped against existing states by authors of this paper. The regional mappings with states and their characteristics are tabulated in Table 55.2. Based on Table 55.2, it was hypothesized that website users from each of these regions will exhibit different cultural values.

Table 55.2 Classification of Indian states and union territories into culturally distinct regions

	North India			South India	North–east India	
Physiology	Dolichocephals (Long Heads)			Mesocephals (Medium Heads)	Brachycephals (Broad Heads)	
Race	Australoids	Indo-Aryans	Mundaris	Irano-Scythians	Far Easterns	Mongolians
Skin color	Dark	Light	Light	Light Brown	Dark	Yellow
Region	Tribes of South India	Indus Valley to Gangetic Valley	Chhota Nagpur, tribes of Orissa, MP	Mysore & Deccan. East along Narmada & Son valley	Tutikorin Chittagong	N-E India Himalayan Foothills
Language (primarily)	Austro-Asiatic (Nishada)—Mon-Khmer	Indo-European (Aryan)—Dardic + Indo-Aryan	Austro-Asiatic (Nishada) — Mundari	Dravidian (Dravida) — South Dravidian	Austro-Asiatic (Nishada)—Mon-Khmer	Tibeto-Chinese (Kirata)
States	Andaman & Nicobar Islands	Kashmir, Uttarakhand, Delhi + Chandigarh, Punjab + Haryana, UP + MP, Gujarat + Rajasthan Maharashtra + Goa, Daman & Diu, Dadra & Nagar Haveli, Bihar + Odisha, W. Bengal	Chhattisgarh Jharkhand	Karnataka Tamil Nadu Kerala Andhra Pradesh Telangana Puducherry Gond tribes of MP	Khasi tribes of Meghalaya	Sikkim Assam Manipur Arunachal Pradesh Mizoram Nagaland Tripura Meghalaya

55.3.2 Deduction of Dimensions of Culturally Distinct Regions Within India

Once the subcultural regions within India were mapped as depicted in Table 55.2, three regions were identified for study. The regions are North–east (Sikkim, Assam, Manipur, Arunachal Pradesh, Mizoram, Nagaland, Tripura, and Meghalaya), North (Kashmir, Uttarakhand, Delhi, Chandigarh, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Gujarat, Rajasthan, Maharashtra, Goa, Daman & Diu, Dadra & Nagar Haveli, Bihar, Jharkhand, Odisha, and West Bengal) and South (Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Telangana and Puducherry).

Representative participants for each state of each region were approached to participate in the value survey. The value survey was conducted online. A total of 340 participants from three different Indian regions were surveyed using VSM 2013, out of which total 312 valid responses were analyzed (Table 55.3). The sample size was selected on basis of a statistical thumb of rule where a sample of 171–384 yields an error of 5–7% if the total population is larger than 5000 [27]. To reduce the influence of other demographics, respondents were matched on gender, age (respondents were between 19–29 years), level of education (undergraduates and graduates), and occupation (students and fresh graduates). To account for the difference in number of responses from each state, means of each state for each region were analyzed using two factor ANOVA to make sure that this difference does not affect the data reliability. Cronbach's alpha values for 24 content question means of each state, for the three regions across the three categories of 'total respondents', 'males', and 'females' were found to be much higher than 0.7, which indicates good reliability of responses across each region (Table 55.4). Culture dimension formulas from VSM 2013 manual [24] were applied to the overall means of the three regions across these categories to identify power distance, masculinity,

Table 55.3 Number of respondents (male/female) from three different Indian regions

	North–east	North	South	Total
Total respondents	67	142	103	312
Males	37	104	55	196
Females	30	38	48	116

Table 55.4 Cronbach's alpha values for mean responses of content questions for states

	8 states of North–east	19 states and union territories of North	6 states and union territories of South
Total respondents	0.852	0.939	0.914
Males	0.730	0.925	0.886
Females	0.720	0.892	0.893

collectivism, uncertainty avoidance, indulgence, and long-term orientation for each region (Table 55.5).

The results in Fig. 55.1 indicate a clear visual difference in the culture dimensions across the three regions. Another insight is the difference in culture dimensions in males (Fig. 55.2) and females (Fig. 55.3) particularly for PD, IDV, and IVR in the North, IDV, UAI, and LTO in the South and MAS, IVR in the North–east.

Table 55.5 Obtained values for Hofstede's culture dimensions for the three regions

	Power distance	Individuality	Masculinity	Uncertainty avoidance	Long-term orientation	Indulgence
NE Total	**6.19**	**9.40**	**6.79**	**48.67**	**19.69**	**9.69**
NE Males	6.22	10.41	7.99	49.22	19.57	0.92
NE Females	9.19	14.68	14.68	49.77	16.52	21.03
North Total	**15.14**	**16.51**	**11.34**	**29.09**	**25.52**	**11.01**
North Males	17.40	20.19	12.79	25.26	26.18	13.73
North Females	8.95	6.45	7.37	39.58	23.71	3.58
South Total	**20.10**	**34.32**	**3.74**	**17.13**	**8.17**	**21.71**
South Males	20.55	52.82	3.18	3.73	2.09	24.27
South Females	19.58	13.13	4.38	32.48	15.13	18.77

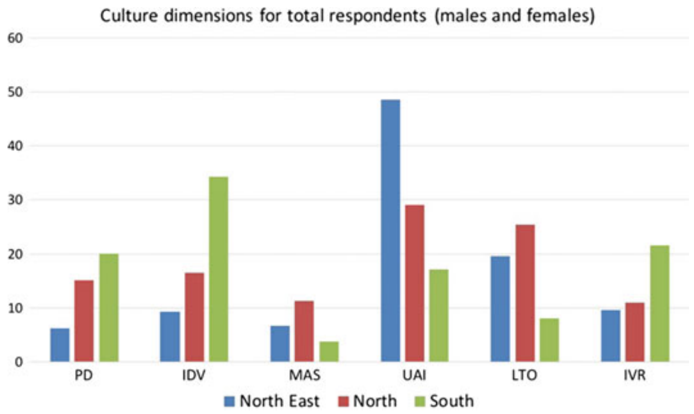

Fig. 55.1 Hofstede's culture dimensions for total respondents in three different Indian regions

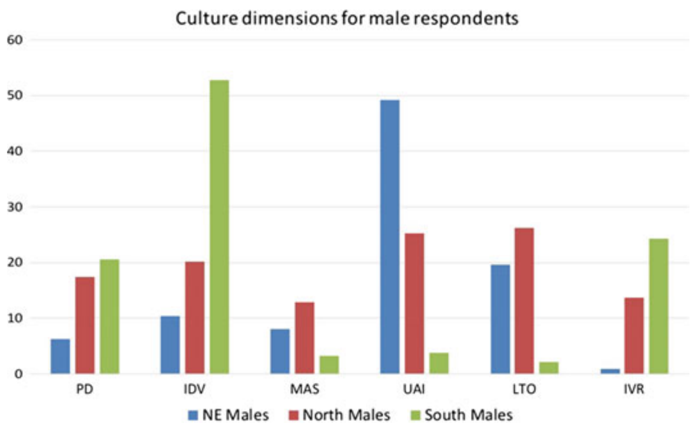

Fig. 55.2 Culture dimensions for males

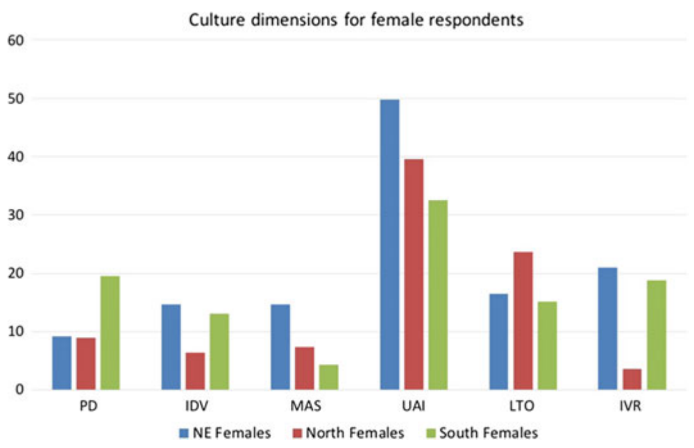

Fig. 55.3 Culture dimensions for females

55.3.3 Study of the Influence of Cultural Differences on Website Designs

To study the influence of subcultural differences on website designs, four-food ordering websites were selected through convenience sampling by five users from each distinct region who frequently ordered food online. The selected websites were popular in their local region and were obscure to users of other regions of the country. The purpose of such a selection was to understand if user interfaces of these websites had cultural implications. A cultural adaptivity table [28] was used to

Table 55.6 Occurrences of user interface aspects of total 12-food ordering websites as per the cultural adaptivity table for three regions in India

User interface aspect	Corresponding culture dim	North–east	North	South
Linear navigation	High PD	2/4	3/4	3/4
Low information at the interface level	High PD	4/4	2/4	3/4
Formal support wizards/error messages	High PD	0/4	2/4	3/4
Restricted navigation	High MAS	2/4	3/4	0/4
High contrast—saturated color palette	High MAS	2/4	4/4	3/4
Content structure around a focal area	High LTO	2/4	2/4	0/4
High information density	High LTO	0/4	1/4	2/4
Linear navigation	High UA	2/4	3/4	3/4
Redundant cues to avoid ambiguity	High UA	2/4	1/4	3/4
Low multimodality	High IDV	2/4	1/4	0/4
Non-traditional color coding	High IDV	4/4	2/4	3/4
Monotonous color palette	High IDV	2/4	2/4	3/4
High image to text ratio	High IDV	4/4	2/4	2/4

analyze the content of the selected websites. Total of 12 websites were fetched on December 21, 2017 whose links are as follows:

http://www.deliverychef.in/, http://www.nightfactory.in/, http://www.foodklik.com/, http://www.foodrool.com/ for the North Indian region; https://www.hommic.com/, http://foodmingo.com/, http://dinein.in/, http://www.chefkraft.com/ for the South Indian region and https://www.baritoz.com/, https://www.foodwoop.com/, https://www.mealsparadise.com/, http://foodnight.com/ for the North–east Indian region.

Table 55.6 lists the occurrences of user interface aspects as per the cultural adaptivity table. Table 55.7 lists the corresponding culture dimension scores derived by the number of occurrences of each indicative user interface aspect.

When compared to subcultural dimensions found from the survey, the occurrences suggested a pattern for PD, MAS, and LTO which was similar to the male population for different regions. The pattern of IDV was similar to the female population, while UA did not match to either.

This suggests that subcultural differences within India might have an influence on user interfaces of locally popular websites. Reasons for the difference in dimensions of UA and IDV can be explored further. This insight can be used in the context of user preferences to develop more evolved interactive website designs for subcultural Indians.

Table 55.7 Culture dimension scores based on occurrences of user interface aspects

	High PD	High IDV	High UA	High MAS	High LTO
North–east	6	12	4	4	2
North	7	7	4	7	3
South	9	8	6	3	2

55.4 Discussion

This paper has used a tool established in literature (VSM 2013) to confirm the hypothesis that distinct subcultural regions exist within India and that there is a significant difference in their culture dimensions. The findings also indicate that these subcultural differences influence the user interface of local website designs, though more detailed studies are required to prove it. The findings from this paper can be used to study local user preferences within India to develop targeted interaction design products and services for Indian subcultures. The findings also show a significant difference in the cultural dimensions of males and females. This insight can pave way for further studies in the domain of gender-specific website design.

This work is novel in terms of its reporting of the subcultural differences in India in the context of user interface design. Previous works studying sub-cultures at national level have yielded insights into consumer motivations and business performances, and mostly been done for the USA, China, and Brazil [12, 29]. Further research to analyze the effect of other demographics like age, income, and profession on Indian subcultural dimensions and its implications on other domains like system design and organizational behavior may help the design community.

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Chapter 56
Capturing Customer Profile Enables in-Vehicle User Identification: Design for Data-Based User Behavior Evaluation

Julia Orlovska, Casper Wickman and Rikard Söderberg

Abstract The majority of user-related studies have been focused on finding similarities and discrepancies in different user behavior patterns. User identification therefore plays a critical role for user-related studies. However, the concept of shared vehicles, where various users have different behavioral patterns that can be joined and mixed under the same vehicle ID, brings greater complexity to the process of user differentiation. In order to be able to separate users' data in shared vehicles, a method for customer profile capturing is proposed. The method design is based on comparisons of every drive cycle to the previously saved data. As a result, this allows with a certain level of likelihood identification of users for every drive cycle. This method design enables the possibility of big data use in more advanced user-related studies.

56.1 Introduction

The runaway enthusiasm for Industry 4.0, digitalization, virtualization, and smart technologies has been widely acknowledged by the scientific community. The automotive industry today generates enormous volumes of data that need to be efficiently utilized at all stages of product development. However, the previous studies [1, 2] show that despite the significant amount and variety of collected data most of the auto-generated data is not user-oriented. This fact makes it difficult to use the data in the user studies.

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The majority of user-related studies focus on similarities and discrepancies in the behaviors of different users, and therefore identification of the user plays a critical role for user-related studies. However, the concept of shared vehicles, where multiple users induce different behavioral patterns that are joined and mixed under the same Vehicle ID, elevates the complexity of different users' correct identification to the next level. Hence, the question we investigate in this research: "Is it possible to differentiate customers in a shared vehicle using only available data?" Consequently, the scope of this paper is to design a method for drivers' identification in a shared vehicle-based solely on sensors data.

We propose a method design for customer profile capturing. A customer profile is the sum of the variables that allow us to identify the user through the personal settings that the driver makes and the driving pattern each driver uses. In this paper, we identify the set of user variables that contribute to the problem of user identification. We discriminate the first and the second levels of data variables according to their value for the user identification process. Finally, we propose a design for data-based user identification.

The design is based on comparison of every DC (drive cycle) with all determined and previously saved customer profiles. As a result, this allows us to identify the user for every DC with a certain probability. Such a construct enables the possibility of using big data in user-related studies.

The paper is structured as follows: Sect. 56.2 introduces the relevant literature and results of previous studies that are related to the current research; Sect. 56.3 presents the design of the process for user identification; Sect. 56.4 discusses the obtained results; Sect. 56.5 presents conclusions and recommendations for further research.

56.2 Background

In the automotive industry, data is traditionally collected and linked to the Vehicle ID, despite the fact that the vehicle can be shared and therefore users' behavior patterns that are collected from different users can be blended. This approach for data retrieval does not give us the possibility to evaluate the users of a vehicle separately, only the combined user behaviors for every vehicle. However, for user-related studies it is extremely important to differentiate users' behavior and keep collected data linked to the particular user (user ID).

56.2.1 Previous Study

In the previous study [2], we came to the conclusion that the user and system performance should be evaluated together in order to understand how system performance affects user behavior. We have found that some attributes of user performance, such as learnability, effectiveness or usefulness, depend on the ability of the system to provide its function.

However, for system performance evaluation, the number of users who provided the input is not important. Eventually, the ability of the system to react adequately to every input it receives is essential. On the other hand, user performance evaluation implies the ability to treat users of the system separately from each other. Consequently, the problem appears when the vehicle purchased for personal use is shared between family members or friends. As a result, it is hard to differentiate users and their performance.

It has become apparent that driver identification is important for cases where the dynamics of usage process need to be monitored. For learnability, it is important to measure the improvement of skills of the same driver over time. Without driver identification, such as in the case of another individual using the car while the measurement process is in progress, the learnability-curve would be biased by the skills of that person that are different from the previously identified user.

User identification is also critical for user patterns analysis. Even close relatives (e.g., husband and wife) who share the same vehicle can show a completely different pattern of activities. Activation of the system, sequences of actions in order to achieve the same result, individual preferences regarding provided functionalities, and speed of personal reactions to different system messages can all vary significantly from one user to another, resulting in bias and altered patterns. At this point, user identification plays a critical role.

56.2.2 Overview of Related Work

The problem of user identification is widely recognized in different fields, and number of attempts have been made to address this issue. To identify users for manufacturing purposes, Robert J. Orr and Gregory D. Abowd [3], designed a smart floor system based on user footstep force profiles. This floor system, with a recognition rate of 93%, may be used to identify users transparently in their everyday working environments.

In the social media, the problem of user identification arises with the necessity to improve online services and advertisement quality across social media networks. Reza Zafarani et al. [4] research users' unique behavioral patterns regarding choice of username across different social media. Liu et al. [5] aim to identify users through their user profile metadata, friendship information, and content-based features. However, these technics differ from our approach, as we deal with distinguishing users within single vehicle and not across different vehicles.

A number of studies were performed in the field of biometric authentication [6–11]. Biometric identifiers, such as fingerprints, face recognition, eye features recognition [10], or voice recognition, are often used in combination with the non-biometric behavioral pattern in order to obtain more reliable results regarding user identification. However, despite significant progress in recent years, these techniques still require improvements before they can be applied in the real-time environment. The use of cars is often associated with rapid decision making and therefore cannot rely on technology that is not fully stable.

Moreover, some of the methods described above are hard to implement because of the specificity of automotive interfaces or due to user permission issues. Due to all of the above limitations of the existing methods and approaches for the user identification process, we are looking for more effective ways to differentiate users in the shared vehicle.

56.2.3 Use of Big Data for the User Identification Problem

Nowadays, one of the established trends in the automotive industry is a smart vehicle [12] with technologies for improving the user experience. In order to make vehicles "smarter," more and more sensors are incorporated to provide robust and updated information about the driving experience, individual settings, and interior compartment adjustments. Those multiple sensors are able to detect and collect user-related information and therefore potentially enable the user identification process.

However, the variety of the available data brings even more questions for investigation: "What data is most relevant for the user identification problem?" and "What value should every user-related variable have in the decision-making process?" These questions are the focus of current study and method design for the vehicle's user identification.

Notably, the variables: *remote key*, *driver profile* or *seat position memory* are primarily designed to save driver's personal preferences, making a transition process from one user to another easier. Personal settings can be saved in *driver profile* and then linked to any of the *remote keys*. Consequently, at the point of the particular *remote key* use, a car will choose the relevant *driver profile* settings. Therefore, for those drivers who use personal settings, the *driver profile*, *remote key* and the *seat position* are the key variables for their identification.

However, the reality shows that the drivers are not saving personal settings to the full extent and still prefer to adjust vehicle manually. As a result, drivers easily share the *remote keys* and *driver profiles*, and we lose track of who is driving the car in a particular drive cycle (DC). To be able to identify these drivers we include additional parameters for user identifications, based on the analysis of adjustments/actions driver performs during every single DC. We save driver's activity, compare it to the activities during the previous DCs and come out with the probability for driver identification. This approach can be useful in cases where two or more users use the same product, such as a shared vehicle, and where a clear logging in function is not present.

56.3 Design of the Study

The goal of this paper is to design a method that helps to differentiate users of the shared vehicle by comparing predefined customer profiles for a particular vehicle to the user identification variables during every single drive cycle (DC). By single DC, we mean one driving activity that starts with the start of the engine and ends with the engine shutdown. Design for data-based user identification consists of the following steps: defining user identification data, creating customer profiles, and identifying the users to be able to sort and store their data under the user ID. This paper presents only the method design for user identification in shared vehicles. Data collection and validation of the method on real users are planned as a next step.

56.3.1 Defining User Identification Data

User identification data is a predefined set of variables that are collected in every DC for comparison with previously stored customer profiles. Therefore, in the beginning we need to define what data to consider as user identification data. To define user identification data, we perform the following steps:

Step 1: We investigate the data flow to look for the signals that have more personalized information than others and can therefore better contribute to the user identification process. We summarize our findings into the dataset of the required data for user identification. Table 56.1 shows the result of selected data for the user identification process.
Step 2: From the user identification dataset, we distinguish the first and the second levels of data variables, according to their importance for the user identification process.

First-level variables are considered critical for user identification and summarily give 75% impact in the user identification process (25% for each).

Second-level variables are cumulative due to the possibility for a user to use few positions within one drive cycle *(radio channel and driving mode)* or change from one drive cycle to the other *(driving route)*. These variables are considered as supplemental for user identification and summarily give 25% impact in the user identification process (5% for each).

Tables 56.2 and 56.3 show the first- and second-level variables together with their possible parameters collected under the customer profile.

At this stage, the user identification data is specified, the first- and second-levels of variables are differentiated, and the values for each variable included in the user identification process are set.

Table 56.1 Data set for the user identification process

Name	Description
Remote key	Remote key is used to lock/unlock the vehicle and must be in the passenger compartment in order to start the engine. A remote key could be connected to the driver profile, but it is not obligatory. That is why we investigate the remote key and driver profile separately
Driver profile	Allows a user to save his/her settings as a profile. Driver profile could include a different number of parameters, including the parameters for user identification. Settings that can be saved in a driver profile: settings in the head-up display, door mirrors positioning, front seats position memory, navigation settings, audio and media system, language and voice control, etc. Keeping driver profile is optional for a user. In this study, we do not consider how many variables are saved under the driving profile, but we track the signal if driver profile is used or not and which one of the saved driver profiles is used
Seat position memory	Gives a possibility to save your seat position and even connect it to the driver profile for automatic adjustment of your seat in the vehicle. The signal we included in the customer profile evaluation is the signal regarding usage of this function. We are interested to know if the function is used or not and which one of the saved seat positions is activated during the drive cycle
Driving route	GPS data detects the route for every driving activity. The number of common driving routes is multiple for every user. In the customer profile, we include only repeatedly represented driving routes (more than 10% of all amounts of DCs for the evaluated period of time)
Driving mode	(ECO, COMFORT, DYNAMIC, INDIVIDUAL, XC, AWD, HYBRID, PURE, SAVE or POWER). The number of modes and their configuration depends on the vehicle model. Not all driving modes are present in every vehicle. However, more than one driving mode could be used during one DC and therefore the variable is cumulative as we need to collect the data regarding all modes used within a single DC
Seat heat	Seat heat is considered to be a part of the routine operations that drivers adjust or save adjustments in the driver profile. In this study, we collect the data regarding activation/deactivation of seat heating and raising/lowering the level of seat heating
Infotainment source	This variable is considered to indicate individual preferences regarding the usage of the infotainment system and therefore is extremely useful for the study matter. We collect the data regarding the activation/deactivation of the infotainment system and considered what type of activation source was used (CD, USB, radio, or mobile phone)
Radio channel	Preferences in using a particular radio channel are also considered to be a good indicator of the user, especially when different users have strong preferences that differ from each other. In this study, we collected the data regarding activation/deactivation of the radio and also considered which radio channel was used

Table 56.2 First-level variables with their possible parameters

Name	Alternative parameters				
Remote key	K1	K2	…	Kn	None
Driver profile	DP1	DP2	…	DPn	None
Seat position memory	S1	S2	…	Sn	None

Table 56.3 Second-level variables with their possible parameters

Name	Alternative parameters				
Driving route	DR1	DR2	…	DRn	None
Driving mode	DM1	DM2	DM3	…	DM10
Seat heat	SH1	SH2	SH3	None	
Infotainment source	Radio	CD	USB	Phone	None
Radio channel	R1	R2	…	Rn	None

56.3.2 Creating Customer Profiles

When the specification for user identification data is set, the data should be collected and the number of customer profiles for the evaluated vehicle is identified. The decision on the number of customer profiles is based on the evaluation of the first-level variables, since the remote key, driver profile, and the seat position memory are clear indicators of a unique user.

Algorithm for creating customer profiles:

(1) Collect a sample of DCs belonging to one Vehicle ID.
(2) Sort DCs into samples where the different remote keys are used.
(3) Evaluate the sorted data samples separately:

- if the use of a particular remote key is repeatedly represented (more than in 10% of DCs for a particular sample)—create a customer profile;
- if the use of a particular remote key is poorly represented (less than in 10% of DCs for a particular sample)—ignore DCs, since creating a customer profile in the case where a particular remote key is poorly represented cannot lead to any conclusions regarding the user behavior anyway.

(4) Evaluate every created customer profile separately. Repeat steps 2–3, this time evaluating the activations of the driver profile variable.
(5) Repeat step 4, regarding the seat position variable representation.
(6) Generate the number of customer profiles. Figure 56.1 shows an example of the process of customer profiles generation.
(7) Extend generated customer profiles by including inherent variables of the second level. For the second-level variables, we need to include only those values that are represented in more than 10% of cases. Figure 56.2 shows the example of defining customer profile 1 with the help of the second level of variables.

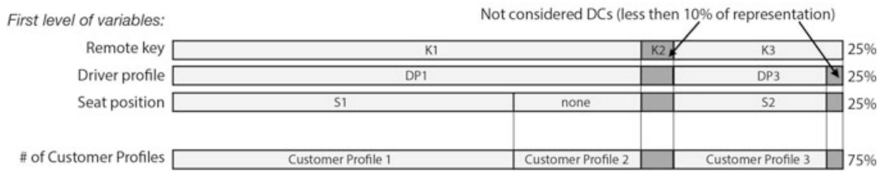

Fig. 56.1 Example of generation of customer profiles

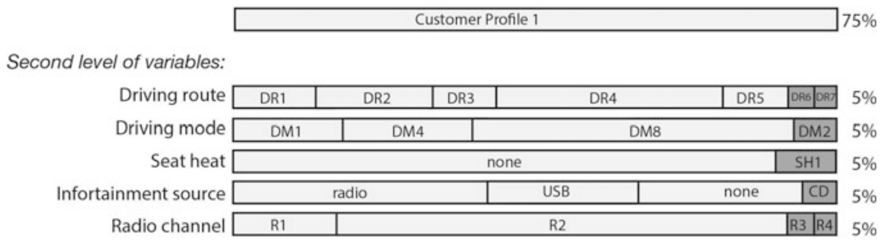

Fig. 56.2 Example of defining customer profile 1

At this stage, the number of customer profiles for the evaluated vehicle is identified and stored under the Vehicle ID.

56.3.3 User Identification Process

When customer profiles are created, we can evaluate the whole sample of DCs and sort user's data by comparing every DC to established customer profiles. If the overall confidence level meets or exceeds a pre-defined threshold value (a match in 85–100% of parameters), we decide that the driver belongs to the particular customer profile and his/her data can be stored under a particular user ID. This data can be used later in different user-related studies. If the overall confidence level is less than 85%, we do not store the user's data under the user ID, due to the high probability of user authentication error. A block diagram algorithm for the user identification process is shown in Fig. 56.3.

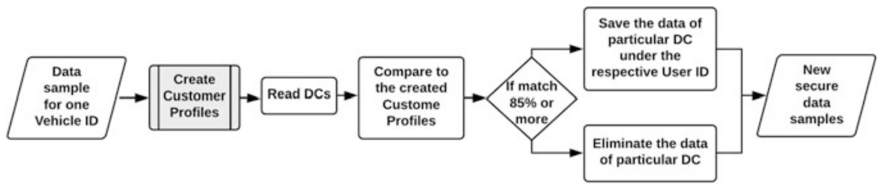

Fig. 56.3 Block diagram algorithm to define a secure data sample

Generally speaking, we propose a design for data-based user identification that allows distinguishing users from a shared vehicle. This design also allows us to sort DCs and store them under the user ID for future user behavior evaluation.

56.4 Discussion

In this section, we perform critical analysis on the accuracy of the user identification data, as well as discuss possible improvements for the design of the user identification process.

The main purpose of the user identification process in this design is not to identify every driver precisely, but to be able to make a secure data sample in order to perform different kinds of user studies. We recognize the possibility of making a mistake and exclusion of some DCs of *regular* users (users with existing customer profiles) or inclusion of DCs from a *random* user (a user who does not have a saved customer profile); however, we think that these rare occasions will not negatively affect the existing pattern of driving activities anyway. Table 56.4 shows the critical analysis of first-level variables for the user identification process.

The only identified possibility for a mistake so far (see Table 56.4) is the situation where a random user borrows the remote key, drives connected to the remote key driver profile, and does not adjust the seat position because it fits or because the DC is short and a slightly uncomfortable seat position could be accepted by a *random* user. In this case, the first level of variables is not able to show us any difference between the *regular* and the *random* driver. However, the second level of variables gives us extra possibilities to detect the *random* user through the cumulative variables of the second level.

We have identified a number of concerns and possible improvements to the design for the user identification process regarding the second level of variables:

– In a condition where the choice of second-level variables does not provide information about user differentiation with a high level of confidence, we have to consider the possibility to include the following set of second-level variables: mirror positions, dashboard and cabin illumination, mobile phone connection,

Table 56.4 Matrix of decisions based on first-level variables

Name	Possible variations							
Borrowed remote key	–	+	–	–	+	+	–	+
Adopted driver profile	–	–	+	–	+	–	+	+
Accepted seat position	–	–	–	+	–	+	+	+
Possibility of mistake	–	–	–	–	–	–	–	+

seat ventilation, and driver display skin. These variables could extend the list of the second-level variables due to the possibilities to provide even more personalized information regarding the usage of a vehicle by different users. The reason why we did not include these variables in the existing design is that we want to keep the process of user identification as simple as possible.

– If data shows strong preferences regarding usage of only one parameter for the particular variable during the measurement period, a higher value can be assigned to this variable in the user identification process. If data shows the use of multiple parameters during the measurement timeframe, the assigned value can be decreased.
– For the second level of variables, the number of the parameters could be less important than the time the user spent in different modes or listened to different radio channels. Therefore, the assigned value can be differentiated by the time spent.

During the design validation stage that we are planning as next step, possible improvements to the design will be considered. The number of second-level variables and the distribution of values will be a focus of the validation process.

56.5 Conclusion

The proposed design for user identification allows user data to be sorted and stored as secure data samples under the user ID for future user behavior investigations. A secure data sample means that we can say with a high level of confidence (85–100%) that the data belongs to the same driver. We understand that using this design for user identification, we exclude a number of random users, but we focus mainly on users who show regular activity, since we want an overview of their behavioral patterns or to investigate their extended performance.

The design presented for data-based user identification enables the possibility of using big data in user-related studies. Advances in data analytics allow UX engineers in the automotive industry to identify existing customers and to evaluate their driving behaviors (e.g., level of activity and choices they make). Consequently, through the synergy between a data provider and UX engineers, information resources can be optimized, and the behavior of new user groups can be documented and studied. The ability to access this information can lead to the development of new smart solutions for customized interfaces in the automotive industry.

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Chapter 57
Redefining News Delivery—A Case Study of Communication Strategies Using HCI-Based Approach

Subhrajit Datta, Nandita Bhanja Chaudhuri and Debayan Dhar

Abstract News plays a significant role in society by affecting people's consciousness. In the current scenario, news is circulated in a way utilizing multiple media and through different channels of communication. The study reported in this paper is a case study approach undertaken to analyze existing formats of news communication, identifying their pain points and frustrations. Literature in communication media highlights different frameworks and strategies for effective communication but hardly talks about customized news based on user profiles. The current study analyzes different medium of news delivery, establishes a format for assessment and proposes an approach of news communication by designing contextual and content-based features specific to news content and its readers. The new concept proposed has been prototyped and tested with end users. The results of user testing are significant as it establishes a new approach to content generation and circulation.

57.1 Introduction

News, a form of mass media [1], plays an important role in delivering news to the general public. It communicates through different media channels like printing, broadcasting, electronic communication and word of mouth. These different types of communication channels can broadly be divided into two main categories viz. tangible channels and intangible channels (Table 57.1). News content and its communication is a dynamic and continuous process but most of its delivery systems rely heavily on traditional methods of textual data entry and information

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presentation (as in newspapers, magazines, Web sites, blogs, email, etc.). This manual process of communication of news content through ICT enabled channels has hardly changed over the period of time. The manual approach is prone to human errors during data entry and content creation. It is pertinent to highlight here that any incorrect information presented as news content can lead to catastrophic events in society. The current system, therefore, requires attention from designers to ensure human errors in news content creation is minimized. Apart from concerns of news content creation and communication, relevant news content identification by readers is also an area that requires attention. In any particular day, an end user receives news from different sources amid a continuous struggle to find relevant news that makes sense for him in the given context [2]. Readers less than fifty years of age are hardly motivated enough to read the entire news story. They prefer to scan through news articles and as such have been observed to get rarely influenced by it. [3].

The situation worsens further as the reader gets constantly confronted with news content from multiple media outlets like newspapers, television, social networking, Billboards, books, etc. each having their own priority and preference in presenting news articles to the readers. A pertinent question, therefore, to raise here is, do existing communication strategies of news delivery across multiple media effectively influence reader's decision-making ability. By communication strategies, it is meant—the various methods and modes of presenting news articles across multiple media outlets. The current investigation presented in this paper intends to address the issue raised above from the perspective of a designer. A detailed literature review has been conducted and reported that highlights the various issues with existing communication strategies across multiple media. Later, a novel concept that addresses the concerns of existing communication strategies of news has been conceptualized, evaluated with end users and presented as a way forward to reimagine news delivery for the next generation.

Table 57.1 Categorization of news sources

Tangible news media	Intangible news media
1. Newspaper	1. Television
2. Magazines	2. Radio
3. Pamphlets	3. Email
4. Books	4. Social media
5. Banners/posters	5. Web sites
6. Billboards	6. Blogs
7. Blimps	7. RSS feeds
8. Augmented reality advertisements	8. Podcasts
9. Placards	9. Films and documentaries
	10. Public speeches
	11. Peer to peer communication

57.2 Background and Related Work

In a way to increase engagement and influence public opinion, newspapers often display sheets across streets [4] (Figs. 57.1 and 57.2). In this traditional format, paper sheets are used as a mode of delivery and readers read out news content presented in sheets according to their preferences and tastes. Television channels, on the other hand, use the anchor to deliver news content to general masses. The idea here is to mimic human-to-human communication and influence readers mind by delivering news content according to the preference of news agency. TV and newspapers generally follow traditional and generic process of delivering news [5] as shown in Fig. 57.3. An important aspect to highlight here is that events happening around are shortlisted and weighted based on the preference of content editors and then presented to readers through the media be it newspaper or TV. So, in a sense, readers are exposed to news content that is pre-identified, shortlisted and presented by the news agency according to their preferences and tastes.

Fig. 57.1 Demonstration of 'dazebao' in the wall of a street in China. [6]

Fig. 57.2 People reading newspapers pasted on a wall in Old Dhaka. [7]

Fig. 57.3 Traditional model of news delivery

The intangible media, specifically the Internet and web-based news media use sophisticated web technologies and multiple channel formats for delivering news content, most prominent among them are the social networking channels like Facebook, Twitter, etc. Other channels include web pages, mobile applications and online videos. Web-based news media utilizes multiple strategies like customization, personalization, categorization of content based on historical user data for delivering news content, assembled collaborative filtering, contextual suggestions and capturing television highlights into a database for future retrieval and reuse [8–10]. The benefits of a technology-driven news media are enormous over traditional news media news delivered by tangible media takes more time to reach readers, while intangible media does it almost instantaneously with better accessibility. Apart from that, tangible media follows a unidirectional approach whereas intangible media the Internet allows communication which is bi- or multi-directional. But, web-based news media has its own challenges as well. It includes scalability of news recommender systems because of overload of online news articles and their unstructured format; difficulty in capturing interests and preferences of users as those are continuously changing; difficulty in recommending articles as shelf lives of news items varies drastically over user's interests, location, culture, etc. [11].

In summary, the literature review highlighted:

1. Intangible media specifically, Internet and web-based news media have a greater reach in comparison with traditional tangible media.
2. Technological advancements provide a greater scope for devising new strategies specifically for Internet and web-based news media.
3. The paucity of literature exploring issues on the Internet and web-based news media.
4. Innovative approaches to content classification, categorization, customization and personalization have been studied widely in various contexts except for news delivery.

News and its context is different from other context as the reader here comes with multiple anticipations like, one who access news continuously for their general needs, those who desire to get current news, those who intend to beat the boredom, those who intend to break monotony of life and those who wish to get status of society [12]. Existing features used in Internet and web-based news media are largely generic which are widely used across various web platforms irrespective of the content and context. Specific features that only cater to the concerns of news readers and its content has hardly been explored by researchers in the context of web-based news delivery. The study presented here focuses in this aspect of designing features for web-based news delivery and presents a concept that is driven specifically based on the context and content of news.

57.3 Research Gap

The aim of this study is to redefine web and Internet-based news delivery strategy based on the identification of contextual and content-specific features of news readers by adopting machine learning approach.

57.4 Methodology

The design process in this context is demonstrated in Fig. 57.4. Initially, an online survey was carried out to capture and comprehend behaviors of news readers. Thereafter, semi-structured interviews were conducted to gather detailed insights. Later, affinity analysis was carried out to generate leads for concept generation. Finally, one of the many concepts generated was prototyped and evaluated with end users.

57.4.1 Online User Survey and Initial Analysis

Initially, an anonymous online survey was posted in a Reddit forum. The objective of the online survey was to identify which type of media—tangible or the intangible one news readers generally prefer. A total of 46 responses were received from various parts of the world (Fig. 57.5). Major respondents were British (23.91%), American (19.56%), French (8.7%), Canadian (6.52%) and German (6.52%). Respondents were primarily from the age group of 18–29 followed by 30–45. Intangible news media was preferred by 82.6% of the population. In a particular day, 47.8% of the population read the news in the morning while 34.8% in the evening. A total of 43.5% of the population scan news while 21.7% prefers to track-specific news content.

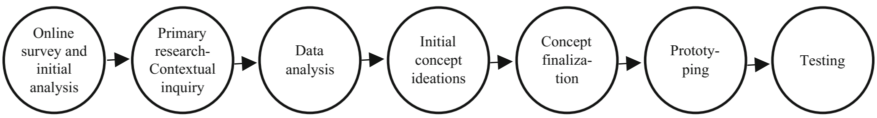

Fig. 57.4 Methodology implemented

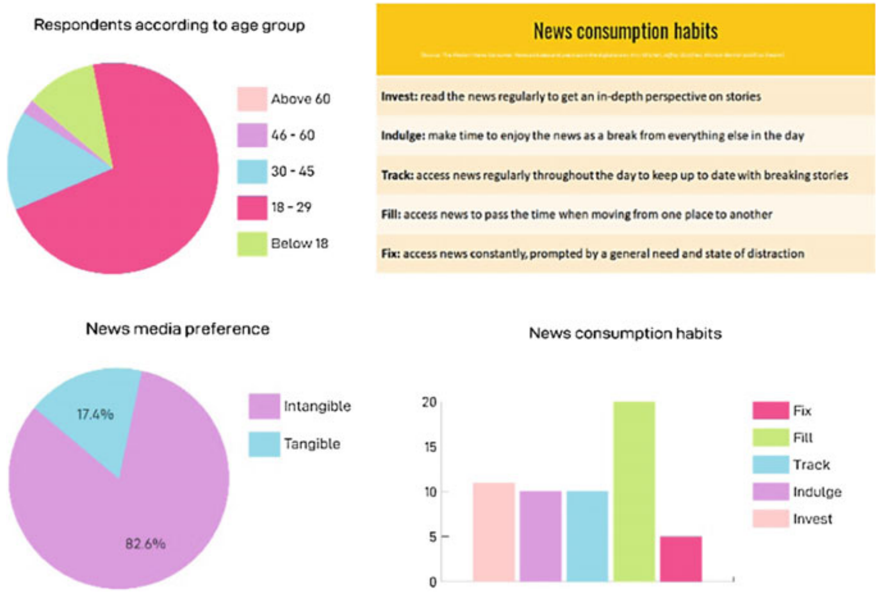

Fig. 57.5 Online survey results

57.4.2 Primary Research-Contextual Inquiry and Data Analysis

With an intention to generate deeper insights, qualitative user study (contextual inquiry) was conducted. Six subjects were asked open-ended questions (semi-structured questionnaire, Table 57.2). Findings suggest that people scan news content rather than reading it, they skim quickly, reading headlines and introduction to see what interests them. Most of the people prefer intangible media over tangible media. They would prefer a different format of news delivery but would not prefer to get involved in a peer review system like Wikipedia.

57.4.3 Design Requirements-Initial Concept and Ideations

Initial concepts revolved around the idea of a web-based system that can extract relevant news, judge the credibility of the news content and delivers important information to the user based on their tastes. The user generates metadata which can be used by the system to learn and provide better insights. News related to the reader's location coupled with health- and environment-related contents can be considered for generating more meaningful insights. Summarized pointers as features if accommodated by the system can help and influence the user.

Table 57.2 Contextual Inquiry—Data collection and affinity analysis

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Notes
Age group	18–29	18–29	18–29	18–29	18–29	30–45	83.3% *users in* 18–29 *age group*
Most used news media	Television, social media, Web sites	Social media, blogs, films/video	Social media, Web sites, RSS feeds	Social media, Web sites, blogs	Social media, Web sites, RSS feeds	Television, newspapers, social media	*Only* 1 *tangible, all others are intangible*
Time	Evening	Evening	Morning	Morning	Evening	News related to work is preferred in the morning and other news in the evening	*Morning and evening are preferred*
Habit	Track	Track	Fill	Fill	Invest	Track	*Only* 1 *user invests, hence truly engages*
What do they believe more—newspaper, news agency or Wikipedia	Wikipedia	Wikipedia	Wikipedia	Wikipedia	Wikipedia	Wikipedia	*All prefer Wikipedia*
Need anything new?	Maybe	Ok	OK	Yes	Yes	Yes	50%—*Yes* 33.33%—*OK* 16.67%—*Maybe*

(continued)

Table 57.2 (continued)

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Notes
What's the need?	–	–	–	'It will be like a block chain for generating news'	'Current media is going through transition and social media is largely equating towards fake news.'	'If news helps in decision making easier it would be great'	50%—*Pinpointed the needs while the rest are unsure*
What form?	Public speaking	Blogs and social Media	Web sites	Intangible	Intangible 'as it can easily reach masses'	Mobile-based	*General consensus is intangible media in differe-nt forms*

57.4.4 Architectural Framework

The initial concept was further elaborated and a web-based news application framework conceptualized. The proposed system is divided into two parts—one that analyzes news content and the other that analyzes readers and profiles them to match their data from both parts so that useful information can be extracted and recommended. Source-specific information is extracted through wrappers and RSS input from the news to gather highlights. Semantic information such as news categories, nouns, and named entities are identified and classified using constantly evolving knowledge base through machine language. The extracted news highlights are aggregated and stored in the database. The server gets the resultant filtered contents from the database for semantic matching. The server stores the news item's indexes and matches it according to the users' model only.

To provide effective pointers, user's information is gathered while they create their profiles. Additionally, the metadata from the user's device can be used too. Machine learning algorithm is used to generate adaptive user models based on the data gathered and also identify if changes are made in the user's interests [13]. The metadata generated by the users is forwarded as short-term and long-term interests for personalization. The usage patterns give the short-term interests by assigning nouns and named entities (quite similar to the server side) and stored in the user's device while data given by the user during creation of profile and form filling gives long-term interests which are forwarded to the database directly [14]. This can be helpful in various ways. One example can be—if a user moves to a different location but the system offers him items related to his previous location, it will be redundant. Similarity-based measures and Bayesian methods are used to learn and adapt to changing user interests. The former can represent the user's short-term interests while the latter, the long-term interests. Both these short-term and long-term learning processes are important for the consistency of the system.

Personalization and filtering done here help to optimize the heft on the server infrastructure. Semantic data matching from both the server and client sides are carried out to provide the most important pointers on the user's device according to time, location and interest. The pointer should be relevant to the user without reading the entire news story. The pointer is improved by giving temporal insight [15]. It is important for the user to understand what incident happened when and what incident is going to happen when so that he can act upon that. This can be accomplished by adding temporal phrases such as 'next Wednesday,' 'yesterday' or 'two days later' along with the pointer that helps the user understand the context and time line of events. The pointers are accompanied by small single sentences which urge the users to act upon the news items and make decisions. This is accomplished by machine learning [16] based on hierarchical models of language which can make suggestions based on the subject matter of the news items and the user's individual data and preferences (Fig. 57.6).

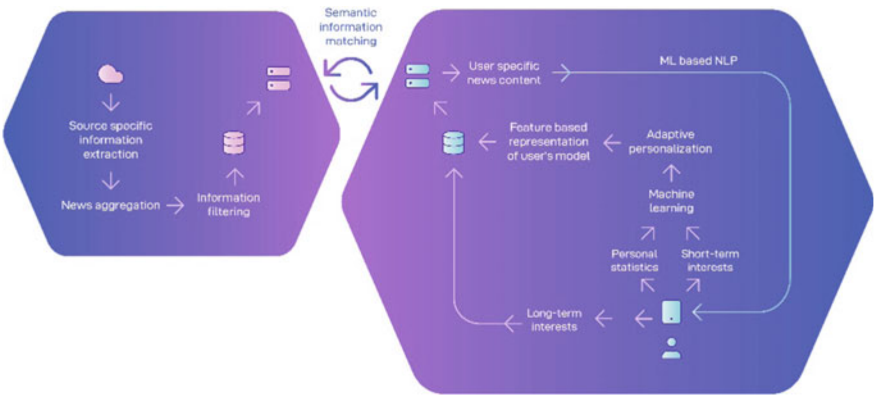

Fig. 57.6 Proposed system architecture

57.4.5 Concept Finalization-Proposed Design Concept

NIRNAY—a web-based application with the tagline ‘Intelligent updates -> Wise decisions.’ The name is derived from the Sanskrit meaning of the word ‘decision.’

It presents daily news content in the form of pointers according to the users’ individual topical interests and preferences. The target user group is 18–50 years old who mostly want news updates regularly. The scenarios considered are a person on his/her commute to or back from office/workplace; a jogger who just finished jogging and cooling off; a person inside a congested bus stuck in traffic who happened to get a seat; a person trying to maintain a healthy lifestyle.

57.4.6 Prototyping

On-boarding screens were made for first-time users. In the home screen, a tabbed module was kept for easy navigation between the three categories of location, health and environment. In the news updates cards, link to the original source of news was given along with an intent menu for easy sharing. A web-based prototype was created which was used to test the usability and functionality of the application as shown in Fig. 57.7.

57.5 Results and Discussion

A task-based user testing was carried out involving four participants. The experiment was preceded by an orientation (by observers) about the purpose and goals and of the application. Three tasks which were to be performed sequentially were

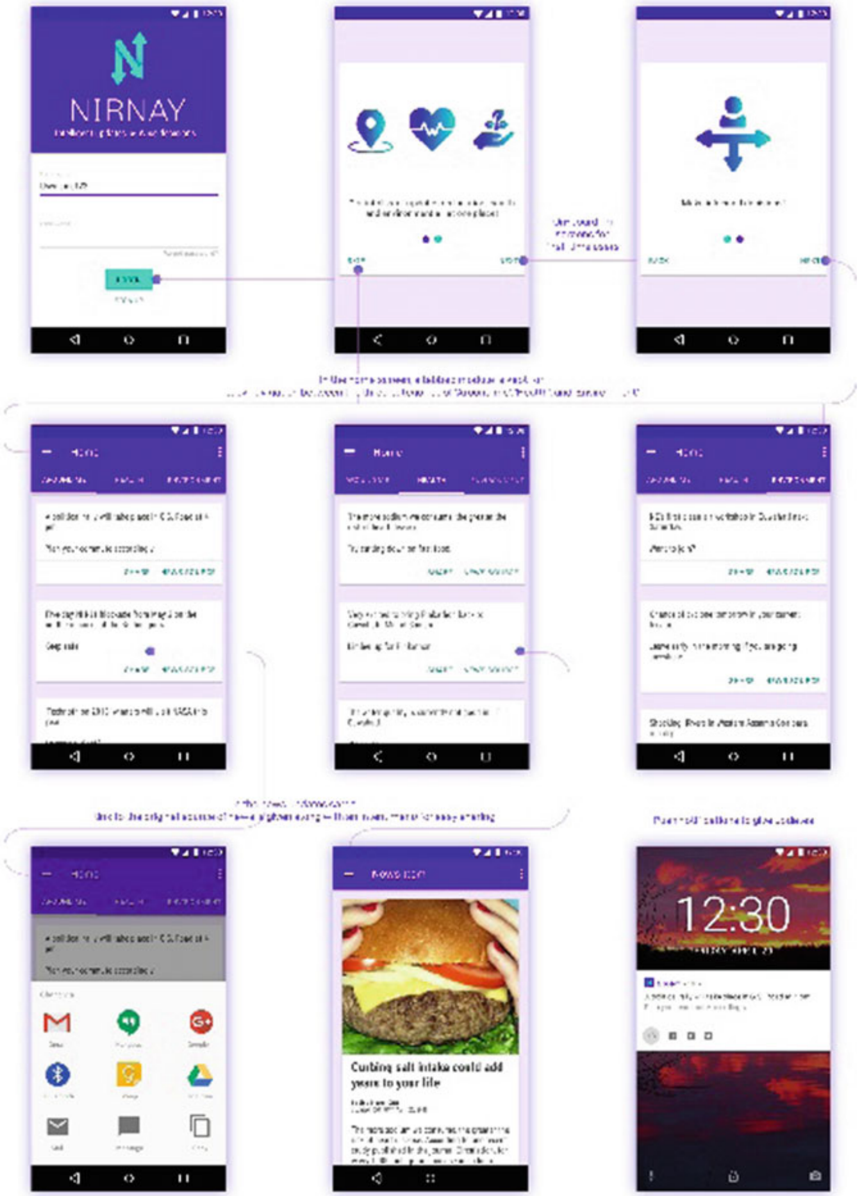

Fig. 57.7 High fidelity prototype screens

given to the users verbally (after the first task was over, the second task was given verbally and so on). Tasks were designed so that the participants use all the features of the app which were to be tested. Users then rated their task experience in a system usability scale (SUS) [17]. The tasks given to the users were—to log in the app and sign out from the location page, locate an update related to fast food and read the source news article and share the update related to clean air workshop with your friend. After completion of the tasks, open-ended questions were asked regarding the features of the application. Four subjects (2*: Male,* 2*: Female; average age:*25.25 *years)* were selected for user study with no intellectual disability and color blindness. The average SUS score is 78.125. The users liked the new features and expressed their willingness to continue to use such a system.

57.6 Conclusion

The feedback from users on NIRNAY was satisfactory. The idea of getting pointers based on news that would influence their decisions without reading the entire news story was exciting for them and the need for authentication of news was preferred highly. This suggests that contextual and content related features of news delivery through web-based media might affect the reading behavior of users and influence their decision making.

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Chapter 58
Health-Centered Care Based on Co-Designed Cyber-Physical System

Renato Basso Nabuco, Anderson Orzari Ribeiro and Luciana Pereira

Abstract Health insurance business models do not "ensure" health. Instead, traditional systems have been designed to treat disease, not well-being. Health promotion is a process that encompasses the physical, mental, and social welfare. Therefore, how could the health insurance business be incentivized to promote health instead of treat diseases? In order to answer this challenge, we have designed a service based on the notion of social ecology as part of the user experience. The strategy is to move toward a co-design philosophy which implies a partnership among patients, professionals, and community working together in the design process. As a methodology, we followed the cyber-physical system (CPS) approach. The CPS, which are systems of collaborating elements that closely interact with their environment by sensing and actuating, is an interesting method to navigate into the healthcare ecosystem. The objective of this paper is to present a human-centered cyber-physical healthcare system concept that can connect users everyday routine, generating the analytics that guide behavior to promote health.

58.1 Introduction

The healthcare sector encompasses the diagnosis, treatment, and prevention of disease, illness, injury, and other physical and mental injuries, has also undergone profound changes [1]. Based on public policy and technological progress over recent decades, we have seen improvement in the access to medical services, the evolution of diagnostic medical equipment, and less invasive therapeutic methods [2, 3].

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Advances in activities assisted by big data through smartphones, 3-D printing, gene sequencing, cloud computing, wearable devices [4] are changing the way patients can actively participate in medical activities and health promoting [5]. Moreover, the combination of data from various sources and the integration of computational algorithms and real-world ecosystems, the cyber-physical systems [6], are considered the next generation of embedded systems that are interconnected, collaborating and will provide a wide range of innovative applications [7, 8].

As a result, life expectancy has been improving globally at a rate of more than 3 years per decade since 1950. For instance, the world average has up from 48 to 71.4 years. Meanwhile, between 1940 and 2015, the life expectancy in Brazil has increased from 45.5 to 75.5 years [9]. In 2030, we will live up to 79.5 years.

The demand is to ensure the economically active population is aging well. In order to achieve that, an emphasis on health promotion is necessary. According to the First International Conference on Health Promotion (Ottawa Charter) [10], health promotion is the process of empowering the community to work on improving their quality of life and health. In addition, it assumes that each individual is in charge of his or her own process to reach a state of complete physical, mental, and social well-being.

One way to encourage health promotion has been the workplace-based wellness programs. In this case, an employer might benefit from investments in employee wellness [11, 12]. However, big companies have more resources and economies of scale necessary to implement and accomplish broad savings through employee wellness programs. Moreover, those enterprises are more likely than small employers to offer insurance [13].

The business model of health insurance today is unfair for small business. The insurers charge a high premium even for healthy small groups because they could become a high risk if one or two members suffer a serious illness or injury [14, 15]. Furthermore, today's health insurance business models do not address the health promotion approach. Instead, the traditional systems are designed to treat the disease not to prevent it. Therefore, how could it be a concept system idealized to promote the health of people who do not have health insurance or workplace wellness programs, such as the employees from small companies?

To address this challenge, firstly we need to understand for whom we are designing for. The strategy is to design a service based on the approach of social ecology as part of user experience [16] and move toward a co-design philosophy. Co-design in healthcare services implies a partnership between patients, professionals, and community working together in the design development process [17]. The co-production uses people's capacities to deliver public services in an equal and reciprocal relationship, shifting the balance of power, responsibility, and resources from professionals to individuals [18].

This paper is organized as follows. Section 58.2 describes the theoretical foundation that drives the research. Section 58.3 introduces the methodology used throughout this paper. Section 58.4 then combines the results from the individual sections to present the new concept. Finally, Sect. 58.5 presents our conclusions, limitations, and future research.

58.2 Theoretical Foundations

58.2.1 Cyber-Physical Systems and Healthcare

Cyber-physical system (CPS) can be defined as multidisciplinary systems capable of conducting feedback control on widely distributed embedded computing systems by the combination of computation, communication, and control technologies [19, 20]. CPS works with the transformation and integration of the existing network systems and traditional embedded systems. The CPS involves embedded computer and networks, monitoring and controlling the physical processes. Physical processes affect computations by feedback loops and vice versa [21, 22].

The recent advances in medical sensors, cloud computing, and wireless sensor networks (WSN) are targeting new healthcare applications of CPS, including in-hospital and in-home patient care. Moreover, this progress provides CPS the ability to analyze the patient's conditions remotely and take actions regardless of the patient's location [23–25]. An analytical system that responds intelligently to dynamic changes in real time could be from integrating physical devices, such as cameras and sensors, with cyber components [26].

In this scenario, Buyya et al. [27] define cloud computing as "a parallel and distributed computing system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers."

The integration of cloud computing and wireless sensor network is an important part of CPS. In their study, Wang et al. [28] proposed CPS architecture for application to the healthcare monitoring and decision support systems, called CPeSC3 (cyber-physical enhanced secured WSNs integrated cloud computing for u-life care).

Banerjee et al. [29] proposed the CPS-MAS, a cyber-physical medical system modeling and analysis framework for safety verification. They demonstrate two examples related to drug delivery for pain relief and chemotherapy. The author believes that a model based on safety verification and the development of safety guaranteed smart medical devices need to happen before the design of CPS.

Lee et al. [30] present a systematic analysis and design of medical cyber-physical systems (MCPS) and the difficulties of managing their inherent complexity. The author draws attention to the multiplicity of challenges on designing a medical system. For them, the new system is not about one single medical device. It will consist of networks of medical devices and computer systems cooperating to provide care to patients. They proposed the concept of virtual medical device (VMD): the set of device types and the algorithm that defines how those devices should interact. Although all the problems with the systems integration and security, one interesting point they have identified is about the caregiver errors in using medical devices, related to stress and overload that are experienced daily. In this way, the authors believe that a user-centered design should be used to validate and to design all the medical devices, as well as the MCPS.

Zeadally and Jabeur [31] have described the different data acquisition for MCPS. Active inputs include smartphones, digital pens, and automatic recognition for a direct digitization of patient data. Sensors of the clinical environment and mobile smartphones constitute the passive input modes. For them, this combination of data coming from various input sources needs to be explored in clinical environments, and the model-based developments and user-centered design are the key to achieve the combination of unconnected information sources for individualized treatments.

58.2.2 Health Promotions and Small Business

There is some evidence that suggests smaller firms are less likely to have successful health promotion interventions compared to the larger workplaces and the implementation of worksite health promotion programs decreases as the size of the workplace decreases [32].

McCoy et al. [33] have conducted a systematic review to determine the quality of evidence of the published literature regarding the barriers to adoption of worksite wellness programs in small business and about the effectiveness of those programs in the improvement of small business worker's health. They were unable to identify any studies that specifically address the hypothesis that large business solutions are generalizable to small business.

Smaller workplaces have some advantages in implementing workplace health promotion: (1) They do not have a big distance between CEO and workers in lower hierarchical layers and this fact can facilitate the communication of the programs; (2) the intimate culture can help in promoting participation of all workers of the organization; (3) the senior leaders can be more accessible and become an ambassador of the program [34, 35].

Nonetheless, there is a principal problem that all companies, big or small, faced when we are discussing about health program: How to motivate people to exercise, take care of their health, and create a healthier lifestyle to work better, live better, and age better?

58.3 Research Design

The purpose of this study is to design a new CPS concept for people who do not have health insurance, such as the workers from small companies. So, the first step is to identify the different user needs related to their own health, based on their daily lifestyle. To create a new concept of a business that is intended to promote health, we need to consider the human being first. We need to understand the different connections that happen every day and the hidden aspects that could represent an opportunity to help people to work on their changing behavior in order to promote health. We need to be more human-to-human (H2H) instead of business-to-business (B2B) or business-to-consumer (B2C).

58.3.1 Data Collection

Interviews were made with 14 (fourteen) different stakeholders to understand different needs and points of view about the healthcare sector, health promotion, and innovations in business models.

The professionals selected for the interviews held positions between management and CEO, have at least 10 years of experience, and they are from different types of companies like: design thinking school, social business, app development, medical clinic, hospitals, health insurance, global technology, bank, laboratory, and government regulatory agency. All interviews were face-to-face, with the exception of two professionals who live outside Brazil that was performed by Skype. Each interview had a different goal.

58.3.2 Online Survey

The author selected the Vila Madalena neighborhood, in the City of São Paulo, State of São Paulo, Brazil. The chosen region has a total area of 8 km and a population of 65.364 in 2010, according to the city Web site. The neighborhood is internationally famous for its cultural activity and the presence of all kinds of small business, like bars, restaurants, advertisement agencies, and others.

Three small business employees were previously selected to receive the online survey. Those selected were asked to share the questionnaire to other workers of small- and medium-sized companies in the same neighborhood, through their contact networks.

The online survey was created using the Survey Monkey© and sent to the selected contacts by the WhatsApp app ("WhatsApp survey"). It consists of 14 questions and the individual does not lose more than 3 min to answer it.

The questions were structured in order to understand the different aspects related to small/medium business employees. We had collected 181 responses.

58.3.3 Data Analysis and Validation

Shadowing is used to gain understanding of an individual's behavior, opinions, and drivers as well as to understand a person's role and paths through an organization or interactions with other objects or people in a given setting. It is used in organizational change assessment, product marketing or positioning, and experience and service design [36]. The technique proposes a researcher to follow a selected individual during the period to be evaluated.

The author closely followed the 03 previously selected, one by one, over a period of 24 h, to draw the customer journey and to collect insights. The "shadowing" provides dense material, detailed qualitative data, and a multidimensional picture about the interactions that the observed user performs during the displacement of their home to their work.

The technique is an important methodology to see and hear things that people usually do not talk about in interviews and surveys. It permits one to deeply get into the people's life and collect valuable insights. After 72 h closely following the three people selected, some important insights were collected:

- People live far away from their jobs, normally in neighborhoods with no safe public spaces, healthy food choices, and access to public health services;
- They cannot afford a gym in the neighborhood where they work or eat healthy food in the area because they are very expensive;
- When there is a transfer along the way, people usually wait for 20 to 30 min, and there is no health food option available at the station;
- During the journey to the workplace, they listen to music (usually some free app from the operating system) and use Facebook;
- Small business employees usually use the food ticket money for another purpose;
- Normally they cook at night, but sometimes they eat an instant noodle at lunch and use the free time to take a nap;
- They do not like to leave work late; the more late, the more dangerous is the place near home.

The effective health promotion is necessarily conducted through behavioral change. We could verify this aspect after realizing that the respondents of the online survey only go for a gym before the summer, to get in shape for the season. According to Fogg Behavior Model [37], three elements must converge at the same moment for a change: Motivation, Ability, and Trigger (or trigger-ing). When change does not occur, at least one of these three elements is missing.

To Valentin-Hjorth et al. [38] "collaborative care models must continuously promote patient 'empowerment', while generating motivation as a driver of 'engagement' and self-efficacy."

Based on those theories and able to understand the motivations and abilities inherent to the user of the system, we can gradually program the "triggers" for engagement and health promotion.

Finally, the design of a new health insurance business model centered in small businesses employees, which simultaneously promote health and is economically viable needs to use the artificial intelligence and combine it with medical knowledge.

58.4 The Human-Centered Cyber-Physical Healthcare System Concept

The proposed conceptual architectural system is presented in Fig. 58.1 and is composed by three groups of layers: (1, 2) Data Collection Layers, (3) Data Management Layer, and (4.1, 4.2) Applications Layers as follow:

(a) Data Collection Layer—this layer provides a unified system access interface for multi-source heterogeneous inputs data. We have two sources of input data: Personal and Professional inputs.

Personal Inputs—the first is data collected from wearable technologies, GPS and user-generated content fed into the system by the user or acquired through interactions on the social networks, when allowed by the user.

Professional Inputs—comes from the different medical information about the user, like medical records, prescriptions, meds, prices from all the clinics, hospitals, laboratories, pharmacy; frequency in the doctors appointments and so on. These layers have physical and virtual interactions, and the system can acquire both data to be processed by the next layer.

(b) Data Management Layer—this layer consists in an efficient storage, high-throughput data upload and download, access control with higher security, power of rapid exchange and retrieval data. The layer also processes massive unstructured data in a real time and offline analysis and integrates all kinds of data mining and machine learning algorithms. The cloud computing is able to process raw data in a variety of structures and formats to ensure the availability and security of the data transmission. The management layer is able to predict the information, learn with the loop-information system and supplies the application layer with the correct triggers, at the perfect time for behavioral change.

(c) Applications Layer—although this layer is separated theoretically, it has the same position from the data collection one. The place where users interact with the system (application layer) is the same as where all the data are collected. The system is configured to enter in a user-loop, where the collected layer captures the

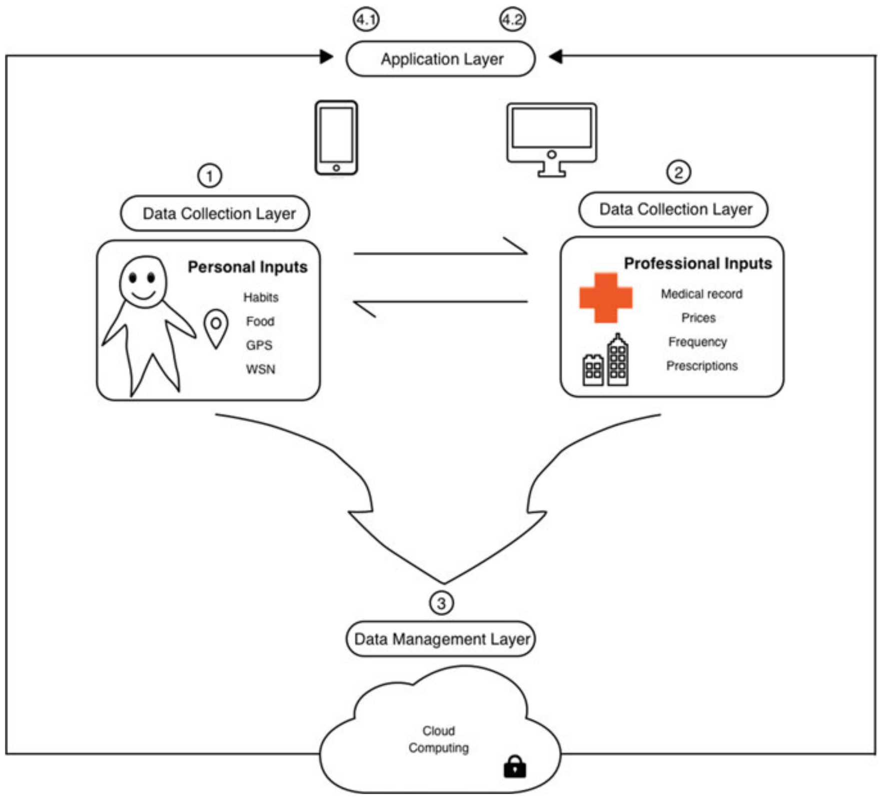

Fig. 58.1 Human-centered cyber-physical healthcare system concept. *Source* Author

different interactions established by the user, throughout all the user-journey, and transformed into processed information by the management layer.

The new concept is designed with the health promotion notion-base and four principles:

- Blockchain technology—blockchain is a digital ledger that allows for data to be stored in a chronological order; the data can be interconnected, but cannot be changed once entered into the ledger;
- Intelligent interoperability—accordingly with the inputs data, the system can understand the "motivations" and the "abilities" of the user. After the information processing, triggers are sent to application layer in order alert the user to your health promotion. Those triggers are sent to mobiles from both users: personals and professionals;
- Mobile technology—the mobile healthcare applications have enabled the technology to be applied in a different manner we had never seen before [39]. The emergence of smartphone-based healthcare applications can address key challenges: the increasing older adult population, the rising worldwide

healthcare-related cost, and to enhance overall healthcare delivery [40], such as the present CPS-health system;

- Increased automation—technology solutions built with electronic communications and process automation as the foundation of the architectural design.

58.5 Conclusions

After the understanding of the whole environment related to the small business employees, through the approach of social ecology and service design, and the use of cloud computing and big data as the approach of cyber-physical systems, the author presents a human-centered cyber-physical healthcare system concept that can connect users everyday routine, generating the analytics that point the way to behavior change on health promotion. Future work can be designed to explore the use of blockchain technology to ensure patient's security information in addition to empowering the user with the responsibility of self-motivation on health promotion.

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Chapter 59
Designing a Learning Aid for Dyslexic Children

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Abstract Dyslexia is a disability which influences one's ability to read, spell and understand. People with dyslexia have reading problems, having nothing to do with social status, level of intelligence or education. Symptoms of dyslexia can be difficult to recognize, but some early clues may indicate a problem. Games have the advantage to keep high motivation. So, games can be used as a learning aid for dyslexic children. This paper discusses a design case study to explore the potential of gamification for improving reading skills of dyslexic children. A digital application was developed as a learning aid and used as a tool to detect the risk of dyslexia at the young age. It focuses on the letter recognition problem which is seen commonly among the dyslexic children. The game is validated using the heuristic evaluation technique. The significance of this game is also discussed in this paper.

59.1 Introduction

The learning disabilities are the imperfect abilities to listen, read, spell, write and organize information [1]. A disorder, where reading is very difficult is one among the most common learning disabilities, is called dyslexia. About 10% of children feel extremely difficult to learn how to read [2]; they need aid influenced by a neurodevelopmental jumble known as dyslexia. Dyslexia remediation is a long way from being completely accomplished, and the present medications and treatments demand high levels of resources [1]. The investigations say that dyslexic kids face impairments to visual-spatial consideration and speech-sound division [3].

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As stated by recent research, playing games could enhance the perusing abilities of dyslexic kids through types of engagement and association. Games that train visually related to space or existing in space also cross-modal temporal attention mechanisms could improve dyslexics read better [4].

This paper is organized into five sections. Section 59.1 presents the introduction, and in Sect. 59.2, we present an overview and the state of the art on dyslexia and motivation of games in education. In Sect. 59.3, we describe the proposed digital game for mobile devices aimed at the self-assistive way of learning letter recognition by dyslexic children. Sections 59.4 and 59.5 discuss the details of the evaluation process and the results, respectively. Section 59.6 is about the conclusion and future work.

59.2 Dyslexia: Overview

Nearly, 10% of the population has some level of learning disability [2]. Learning disabilities include dyslexia (disability of reading), dysgraphia (disability of writing) and dyscalculia (disability in mathematics). The term "dyslexia" was utilized by Rudolf Berlin of Stuttgart Germany in 1887 to describe the children confronting troubles in reading the words and letters. The word dyslexia means "difficulty with words or language" [5]. Dyslexia is not a disease; it is a kind of disability which influences a person's ability to read, spell and understand [5].

Around 80% of individuals with learning inabilities have dyslexia [1], which makes it the most widely recognized learning disability. The deficit in the phonologic component of language is seen to be correct reasons of dyslexia which causes difficulty to utilize the alphabetic code to decode the written word. This causes different metabolic actions in brain and leads to improper storage of information and problems in retrieval. Reading finds to be more difficult than speaking. Active learning is required to learn complex process like read and write [1], supported by a network of regions in the left hemisphere of the brain.

In India, the exact state-wise and language-wise statistical details about the persons affected by learning disabilities are not available. This is expected due to the multilingual system [6], the absence of standardized tools in different languages to assess learning disabilities, the absence of trained manpower to screen for learning disabilities, and moreover it is not visible like other disability categories [6]. Different languages have diverse qualities and diverse requests. Depending on the language, dyslexia will show itself in different ways. On account of understudies with a multilingual foundation, things have a tendency to get more muddled [6]. Mostly the symptoms are neglected thinking it may just be the outcome of the student's sociocultural foundation, the absence of satisfactory learning opportunities or of inadequate teaching methodologies.

59.2.1 Problem Space

The therapy for dyslexia follows worksheets that too in the English language to examine the abilities of the child. According to the experts, these worksheets are used to test reading and writing skills of the child make him embarrassing. According to the experts, these kinds of tests may lead to therapy dropout. Most of the time, treatment is unavailable and unaffordable.

59.3 Proposed Design Intervention

Games provide an individualized educating and learning condition, which may help in the advancement of memory, visual perception, sound-related ability, language, critical thinking, decision-making and problem-solving ability. In this context, the games can be the valuable tool to teach in order to improve their confidence and furthermore enhance the knowledge of children, if the game is designed and utilized with certain objectives. Games have the preferred standpoint to keep high motivation and alert in children; this reduces the therapy dropout rate [7]. Playing computer games, that train visual-spatial and cross-modal temporal attention mechanisms, can make dyslexics read better [4]. Testing reading and other academic skills are one of the factors that doctors consider that can diagnose dyslexia. These tests may embarrass the child and can decrease their self-esteem. Using game-based approach in testing reading and other academic skills can make them feel comfort and confident.

According to the counsellors and research papers, letter reversals and confusion in the sequence are common effects of learning disability [8]. The attentional dysfunction is a critical core deficit in dyslexic people [9]. So, games can be the good solution for letter recognition exercise. The visual attention could be crucial for learning letter identities and their relative positions independently of language knowledge [10]. One of the reasons why dyslexic children face problem in letter identification is that of the crowding [11]. So, the game will be designed in such a way that in beginning levels, there will be no crowding and in later on levels gradually the crowding increases so that this practice makes them to overcome this problem. These children need particular attention to differentiate the shape of letters, especially with the letters b, d, p and q [12] [13] and [8]. For this difficulty, these letters are involved frequently in the game. So, that this practice improves their letter identification. Games have the advantage to keep high motivation and alert in children, thus reducing the therapy dropout rate [7]. The visual attention could be crucial for learning letter identities [10]. So, the colours, images and letters used in the game will be according to the insights of collected data. The suggestions from the counsellors have been taken in designing this game.

59.3.1 Concept of Game

Title of the proposed game is "Lets find letters". The basic concept of the game is "Pick the odd one", but the proposed game consists of correct and reversal letters. The game was made using "Unity" software and "C#" language. The player has to pick the correct letters within the given time. The app presents a grid. The grid has combinations of small letters, capital letters and numerals. The child is asked to click a particular letter from the presented grid. The options consist of similar sounding, similar looking letters and few reversed letters. According to the player performance, the difficulty level of the game varies. The difficulty levels can be increased by increasing grid size and complexity of letters. The player gets a random letter in the grid without repetition. The game solution can be applied to other regional languages. This game is for English and Hindi alphabets and numbers.

59.3.1.1 Features

The correct answer with options: attention can be nurtured through exercises that present the selection of a letter from a collection of other graphemes requiring a quick orientation of visual attention before the application of the correct phoneme-grapheme integration [14].

Number of letters displayed on the screen: one of the reasons why dyslexic children face problem in letter identification is that of the crowding [11]. Displaying few letters makes the game easier for a number of reasons, e.g. the player can better identify the spatial position of letters, and letters are bigger and more distinguishable.

Letters layout on the screen: the way letters are presented in the interface influences the difficulty in identifying the letter, above all for children who are affected by concentration problems. Initially, only two options are given, so that getting correct answer becomes easy to the dyslexic child. This improves the confidence of dyslexic child.

Letter visibility and colour contrast: any letter group can be better distinguished through bounding boxes and high-contrast colour layouts [14]. This visual aid is an evolution of the adoption of DFONT, a monospaced font where letters are surrounded by squares.

Types of options: the options consist of similar sounding, similar looking letters and few reversed letters. These children need particular attention to differentiate the shape of letters, especially with the letters b, d, p and q [8, 12, 13].

According to the in-use terminology of gaming field, we define the concept of a level, time limit and the number of wrong options as a difficulty phase of a given section of the game.

59.3.2 Levels

The levels of difficulty will be presented by the system, depending upon the responses given by the player. According to the player performance, the difficulty level of the game varies. The difficulty levels can be increased by increasing grid size, complexity of letters and time complexity. The player gets a random letter in the grid. There are three levels in this game.

Level 1. The first level is the basic level where the correct letter or digit at random would be presented by the system to the player. The letter comes with an auditory feedback to emphasize and revise the sound-symbol connection. The letter will appear and fade away, and a grid of two letters will appear on the screen. One of these is a correct letter, and another is incorrect. The child has to select the correct one to clear the stage. The player gets three chances to give a correct answer. In the first chance if the player goes wrong then in the second chance the options will be shuffled by the system. In second chance if also the player goes wrong then in the third chance the options will remain same. The player will get point only if he/she answers in first chance (Fig. 59.1).

Level 2. In this level, image and word with missing letter are displayed. There is no auditory feedback. The word for the image is presented in the form of fill-in-the-blanks as shown in Fig. 59.2. The child has to select the right letter from the provided options. This level may help dyslexic child to focus on a graphical symbol and to recognize it against others.

At his cognition level, child is required to do 2 activities:

(1) Find the right word for the image using help from the filled blanks in the question and his memory.
(2) Identify the right letters to fill the gaps.

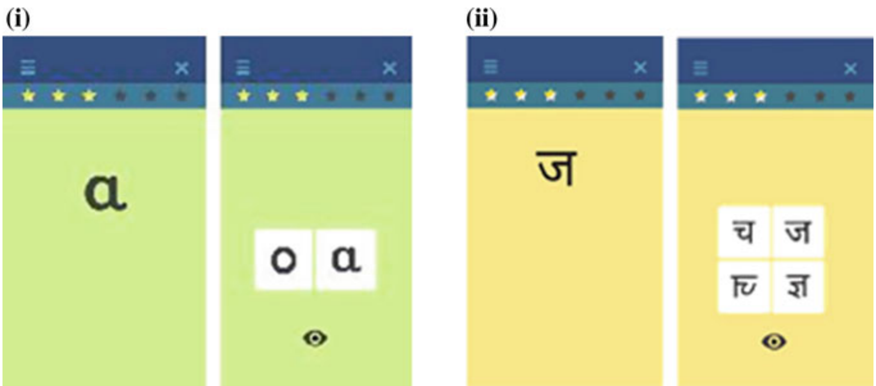

Fig. 59.1 Screenshot of level-1 in (**i**) English and (**ii**) Hindi. The first screen shows a letter which disappears and shows the second screen with 2 options of similar sounding, similar looking letters and reversed letters

Fig. 59.2 Screenshot of level-2 in English and Hindi. The screen shows a word with missing letter and respective image with similar sounding, similar looking letters and reversed letters

In this level, the player gets six options of similar sounding, similar looking letters and few reversed letters in which one option is correct.

Level 3. In this level, the system presents a grid of 9 options in which 3 are correct options. It includes the letters which dyslexics find more difficult, e.g. 5-S, t-f, u-n, m-w, c-u, b-d, p-q. This is the final level to win the game. The system presents a correct letter with audio, and the options grid asked to select the correct 3 options from it. There is also a time limit where player faces increasing difficulties in order to get involved in the gameplay. The level of water in the background keeps rising gradually. The child has to finish the activity before the activity block is submerged completely into the water. According to the in-use terminology of

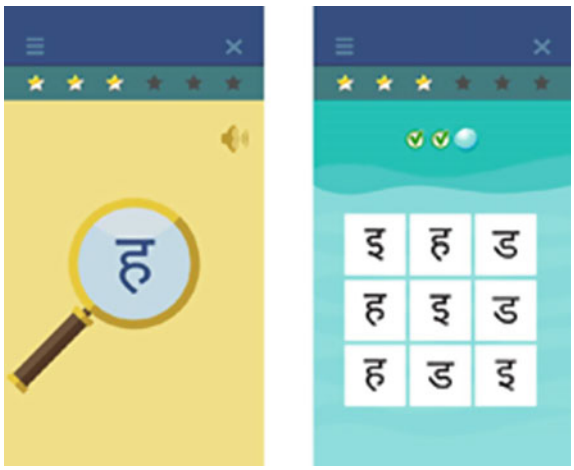

Fig. 59.3 Screen shot of level-3 in Hindi. The first screen shows a letter which disappears and shows second screen with options of similar sounding, similar looking letters and reversed letters. The water level in the background indicates the timer

gaming field, we define the concept of the level, time limit and the number of wrong options as a difficulty phase of a given section of the game (Fig. 59.3).

59.4 Heuristic Evaluation

Usability evaluation is the technique usually used to evaluate the usability based on efficiency, memorability, satisfaction, learnability and error. This technique is used in the field of human–computer interaction. There are various techniques that can be used for usability evaluation. Based on the focus of this study, heuristic evaluation is used as the usability evaluation technique. The objective of this study is to identify problems in the interface of this game that had been developed. The result of this evaluation provides suggestions those can be used to refine the design. Heuristic evaluation of this game is as follows:

59.4.1 Sample of Study

This study involves three experts for the evaluation process. All three were selected based on the qualification and experience related to dyslexia. Table 59.1 shows the profile of evaluators.

59.4.2 Evaluation Process

Questionnaire. The questionnaire for the evaluation of the game "Lets find letters" was prepared based on the Neilsen Usability Heuristics. The questions in the questionnaire are about heuristic for user interface in the context of dyslexia. (Table 59.2)

The questions based on the above heuristics were answered using a 5-point Likert scale.

Evaluation. The game "Lets find letters" was installed in the mobile and demonstrated the game to the experts. Later the game was played by the experts. Next, the experts evaluated the game based on the provided questionnaire.

Table 59.1 Sample

Evaluator	Profession	Experience with dyslexia
1	Professor (psychology)	5 years
2	Research scholar (psychology)	5 years
3	Counsellor	10 years

Table 59.2 Heuristics for interface design

Heuristics for interface design (ID)	
ID1	Visibility of system status
ID2	Match between system and the real world
ID3	User control and freedom
ID4	Consistency and standards
ID5	Error prevention
ID6	Recognition rather than recall
ID7	Flexibility and efficiency of use
ID8	Aesthetic and minimalist design
ID9	Help users recognize, diagnose and recover from errors
ID10	Help and documentation

The experts gave the feedback and suggestions to overcome the problems identified in the evaluation process.

59.5 Result and Discussion

59.5.1 Result from Heuristic Evaluation

The following figure shows the results analysed from the questionnaire. The graph represents the mean score of the results. The overall result indicates that the experts agree and neutral on the heuristics (Fig. 59.4).

According to the experts, the scores of four heuristics are between agree and strongly agree. The scores of the heuristic ID3 (user control and freedom) show that the players have the control over the navigation of the game and freedom to quit

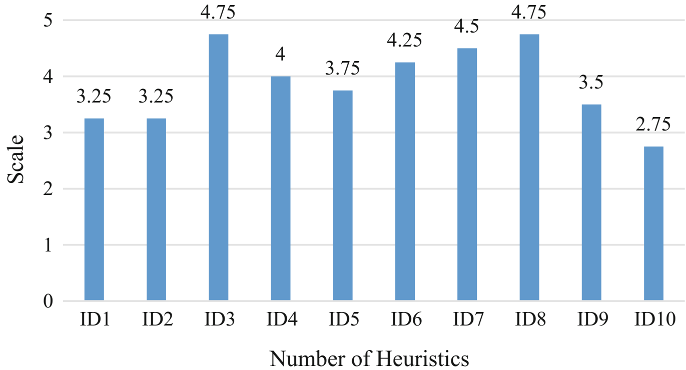

Fig. 59.4 Mean score from heuristic evaluation

anytime. The menu and exit buttons are displayed on every screen of the screen. Learning applications designed for dyslexic children demands minimal graphics because the graphics may overload and misleads the player. Heuristic ID8 (aesthetic and minimalist design) scores show that the graphics, text and colours of the interface are minimal. All the buttons and graphics are easy to recognize and flexible to use. Other four heuristics are between neutral and agree, but the heuristic ID10 (Help and documentation) obtained a score 2.75, which is between disagree to neutral. The help and demo need to be modified to improve the usability of the game.

The overall result of the questionnaire was positive though some of the heuristics obtained close to neutral score. The certain aspects of the game need to be refined based on the heuristic evaluation to ensure the game is ready to try with dyslexic children.

59.5.2 Feedback from Experts

Besides the usability evaluation by three experts, the Assistant Director of Institute for Child Development (16 years of experience in this area) has also given her feedback and comments as follows:

- This game can also be used as the tool to detect the younger age children at risk of dyslexia.
- The graphics are minimum, and the options provided for the questions serve the purpose of the game.
- The experts suggested that the proper demo and help have to be provided before the game starts.
- The experts also suggested to add more interesting levels based on vowels and sounds.

59.6 Conclusion and Future Work

In this study, the game called “Lets find letters” was developed for both as the learning aid and also as a tool to detect the younger age children at risk of dyslexia. The game was prototyped according to the recommendations in the literature. Levels for Hindi are also included in the game to understand the behaviour of dyslexic children within different regional language contexts. Due to the limited literature available in multilingual systems such as India, levels in Hindi test whether differing language has any affect towards dyslexia. In future, other regional languages can also be included in the game. This usability of this game was tested using heuristic evaluation by the experts. Most of the heuristics obtained above average score. Besides the questionnaire, the experts also provided us a positive feedback and suggestions. This evaluation and the inputs given by the experts will be used for the improvement of the game. Once the game is improved, the testing will be carried out by the children with and without dyslexia. The gameplay will be recorded, and their response patterns can be analysed in order to get reliable result. Once the evaluation of the game is done and developed further, it can be used by dyslexic children as a learning aid and by therapists, parents and teachers to detect the risk of dyslexia at the young age.

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Chapter 60
Number Maze: Play and Learn

Mohammed Rajik Khan, Suman Mishra and S. Prathik Yadav

Abstract Evolution of numerical adroitness among kids starts from a very early stage, before entering school. The present work aims to develop a board game "Number Maze" to enhance children's numerical cognition, logical mind, and motor skill ability in the age group of 3–5 years. Using the basic logic that a given number can be expressed as a sum of other small numbers, paths are followed to achieve the target. A prototype design of this game board includes a flat horizontal surface with numerous pathways with a light source, a handheld mover stick, and a display board. A fish shaped layout of the game board is developed for improved interaction achieved from the survey of a sample of 30 kids. Playing with the board game at home may provide the opportunity to gain and attain numeric skills before formal start of schooling. The proposed game could be extended for utilization at schools, home, play zones, etc. along with school-based proficient learning.

60.1 Introduction

A child's cognitive skill enhancement shapes up immediately after his birth; this provokes the path to early intervention strategies. This enrichment is crucial for a child entering school to remain in convenience in further learning. Further, it helps in providing a framework about how the physical materials play a detrimental role in effective learning. Since time immemorial, educational board game with specific content of knowledge has been applied to learning and teaching context. Games as learning tools will arouse positive learning attitudes, enhance learning motivation,

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and increase learning effects. At present, there are various methodologies, systematic procedures, technological innovations, computer games, indoor games, outdoor games, etc. which equip the child with organizational learning. The key to this fundamental learning is proper alignment of learning activities with required mental representation via these games. The count-on procedure used when playing the number board games where children name the numerals in the squares they pass instead of counting the number of steps the die or spinner shows can be seen as a process that indirectly supports the development of cardinality [5]. This has led to the demand of games incorporated with the activation of child's logical domain. Thus, it becomes essential to consider the parameters of design, activities, and interaction in accordance with a child's age to initiate analogical development.

Despite the emergence of the digital devices and the acceptance of electronic games, board games still preserve the value. It displays no sign of descending into obsolescence as have other famous forms of entertainment. Huang et al. [1] have presented an educational board game design course. The study musters about creating an effective way of interactive learning among the kids. Sonnenschein et al. [2] advocate an effective way for teaching the kids how to count numbers. It is an extension of classroom-based math board game for preschoolers. Tan et al. [3] have designed the CALSIUM framework which is a participatory design approach involving active participation of its target users in the early part of the design process. It validates the importance of children in determining the design of an online game for enhancing their social skills. Russo and Hopkins [4] proposed the famous snakes and ladder game, which determines, the person reaching the goal first, as winner. Elafsson et al. [5] have discussed and analyzed the impacts and comfort of playing number amusements on the improvement of number learning and early math. Ramani et al. [6] analyzed whether a hypothetically based number tabletop game could be converted into a down-to-earth classroom action that enhances Head Start kids' numerical learning. Various research and development are still going on so as to make games feasible for both playing and learning.

The new product evolved in the present work strives to achieve enhancement of child's analytical and logical skills through a board game which can serve as a playing and learning tool. By following the cognitive, shape, sound, and color psychology of the kids, the features of the game board were assigned. A group of 30 children (39% girls and 61% boys) participated in the study, which helped us to record their preferences for shape, color, and objects. After the study, all the responses were acutely analyzed to reach the conclusion of the physical features to be adopted in the design in order to make it alluring. The critical path method is used to find the shortest path among the available paths. In a grid-type structure, one has to choose the right path as per the requirement, using a handle to traverse from one of the three starts till the end. This compact and optimized design makes the game easily accessible at various places from schools to homes to shopping malls.

The composition of the manuscript is further organized as follows. Section 60.2 presents the design of the game board: Number Maze. Implementation of the proposed design in a commercial CAD application software is done in Sect. 60.3. Finally, conclusion and future scope are suggested in the last section.

60.2 Materials and Methods

60.2.1 Participatory Study

For the proposed framework, a feedback mechanism has been incorporated to determine the cognitive inclination of the kids. It also paves the way to gain insight into their physiology. Participatory outline ordinarily involves that the members are as comparable as conceivable as the device's potential clients.

Thirty healthy children (09 girls and 21 boys) with no mental or eye illness, ranging from 4 to 6 years of age, participated in the survey. These children belong to a Kindergarten School at Rourkela, Odisha, India. Further, nowadays, the mean age of 5 years is reluctant toward pursuing book-based learning due to their affinity for e-learning. Another reason for selecting the above generation is due to their confidence in declaring their expressions in both written and graphical presentations [2]. Information sheet was provided to all the students prior to the process, and formal consent form was duly signed for approval by the school authorities. The further proceedings took place after formal approval from their parents and teachers along with ethical clearance from the institute to conduct the survey.

The key elements that we have incorporated in the framework are: creativity, activity, learnability, interactivity, and usability. The children participated in two sessions of preference-testing and understanding the objective workshops that spanned over few hours during the school hours. Low technology materials like paper, pens, crayons, boards, and sheets of paper comprising various shapes were provided to the 30 participants. They were asked to mark the favorite choice of shapes/figures and color according to them. All the shapes and figures were not gender biased and were uniformly distributed in the entire set. Figure 60.1 depicts that 80% of boys opted for blue, and 90% of the girls also preferred blue. Also, majority of the children preferred star shape implying multi-vertex shapes were more attractive than the plain linear shapes. Their affinity for butterfly and flower proved their preference for smooth edges and preference for lively objects from nature. This notifies that they are more drawn toward nature-based objects that are active rather than passive objects.

60.2.2 Concept Development

Based on the likeliness and proclivity, as inferred from the participatory study, the preferences of the children let us come up with few frameworks as depicted in Fig. 60.2. The above diagnosis can be affirmed with the research work presented by Tan et al. [3], where it exclusively highlights the process of development of game. The development was divided into two phases: concept and design. Stage 1 of conceptualization involved selecting the framework for the game board, in which various probable layouts were proposed and discussed meticulously. With the

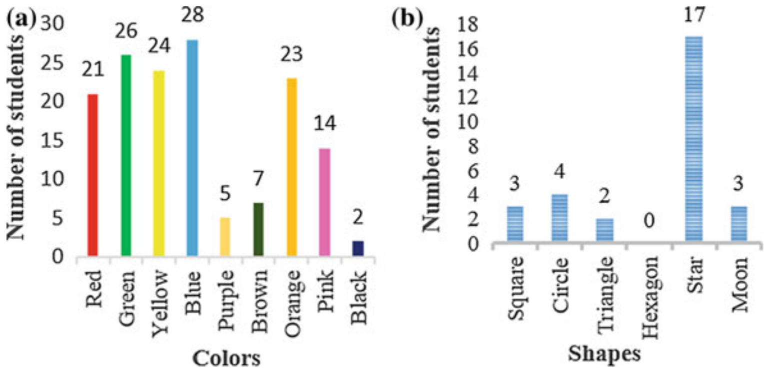

Fig. 60.1 Survey results **a** color preferences **b** shape preferences

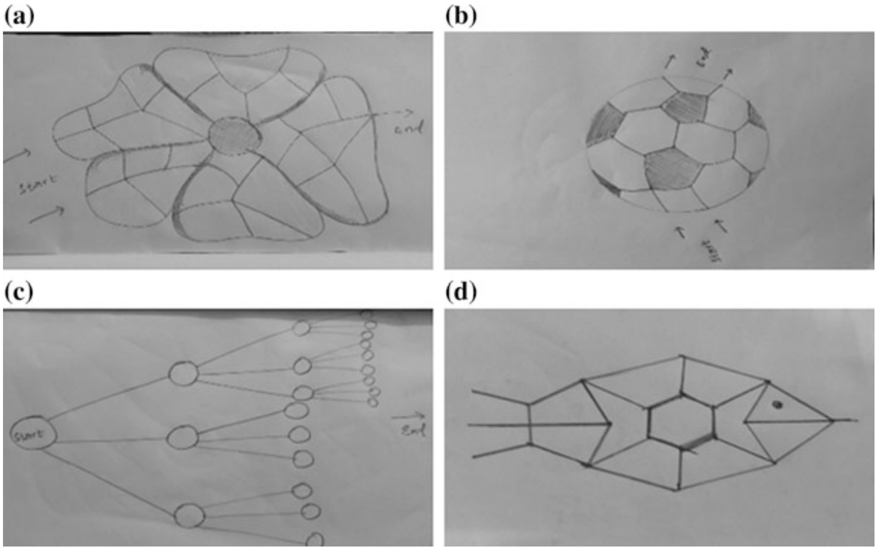

Fig. 60.2 Concept sketches for game board framework depicting **a** flower **b** football **c** side-way bubbles **d** fish

various preferable features that could be concluded from the study, the concept sketches were generated. The shape of flower, which outlines a soft, delicate object with curvaceous framework as depicted in Fig. 60.2a, was chosen. The shape of football, which portrays a round shape, is depicted in Fig. 60.2b. The side-way flowchart of bubbles, consisting of linear shapes, is depicted in Fig. 60.2c. The fish structure, comprising of various polygons, is outlined in Fig. 60.2d. In order to have a simple, feasible layout, ergonomically comfortable movement, clearly perceptible pathways, and contractible feature, the fish layout was finally selected. The key idea was to encompass the associative nature of a child with the object; hence, the designs are not aloof from their mind.

60.2.3 Design of a Number Maze

Number Maze, a typical board game with calculative features inbuilt, emphasizes reasoning as well as strategy choice. It helps in counting, calculating, and determining the number steps to be taken for a path. This device can be used in schools, shopping malls, during travel, etc. It can also be used as a pre-school tool for learning at home. Finally, a framework has been designed in accordance with a living structure, fish, which also satisfies the aesthetic look of the game. Figure 60.3 depicts the two-dimensional orthographic view of the device showing the overall layout and the structural framework. It consists of 31 pathways; each pathway takes the count as 1. The game can be started from any of the paths among L_1, L_{1a} and L_{1b}, which are the opening paths. The paths of the game board have two different widths. While in all the paths, the width is same, but only at junctions J_1, J_2, $J_{3,}$ and J_4, it is slightly smaller than the former. This variation prevents the handle from coming out of the path during play. The overall skeletal structure of the Number Maze Board game is made semi-symmetry along the horizontal center line passing through the output terminal.

Circuit Design

An electronic circuitry system is developed for the automation of the game board to make the system more responsive. For this, we included (light emitting diodes) LEDs in the path from the bottom, a LCD display board, reed sensor interfaced with a latching circuit and an Arduino.

A handheld moving handle is used to traverse the path while playing the game (Fig. 60.3b). The handle is designed as a conical structure with cylindrical base

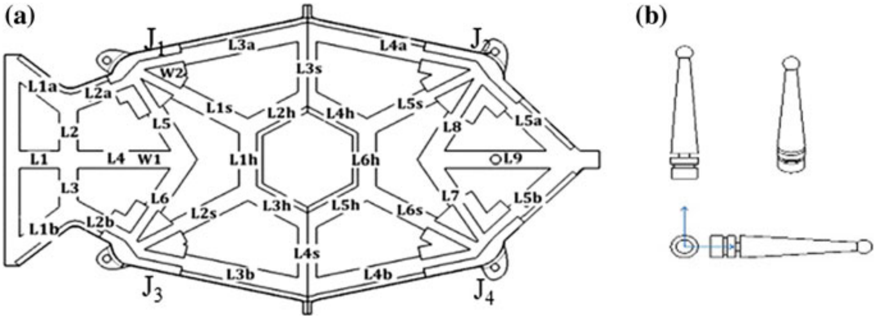

Fig. 60.3 Two-dimensional orthographic view of the **a** game board **b** handle

having circular grooves around the base corresponding to the wall thickness along the roads. This helps the handle to slide easily along the path. The conical surface with a spherical head provides a better grip of children's hand during play. At the base of the handle, a tiny magnet is attached for its detection by a reed sensor attached bottom of the game board during traversing.

60.3 Implementation

The proposed design of the game board is generated in CATIA V6 modeling environment, a commercial CAD software. This software allows the users to generate three-dimensional models. The entire board of dimension 250 mm $\times$ 420 mm is divided into three parts for the ease of manufacturing (as shown in Fig. 60.4). The parts were fabricated in FDM-based RP system (Stratasys, Dimension 1200es) in digital fabrication laboratory at ID department of the institute. The male pins manufactured on the hexagonal edges at every 60° help in the insertion into the female pins attached on the two disjoint parts of the board, which holds them together. Figure 60.5 shows the ABS-based fabricated board along with the reed sensors attached beneath the structure and the circuitry.

The working principal illustrates the determination of combination of paths that equals the enquired value/number (say 10, 12, 13…). It is therefore essential for the user to analyze and establish which path to take before proceeding. Once the user proceeds with a path, the count loop starts computing. It follows the critical path computing method using reed sensor. Each and every path of the game board has a hole exactly at the center of the path beneath where a reed sensor is placed. The handle movement can start from one of the three openings at the beginning, but passing only once through any particular path. As soon as the handle, which has a small magnet attached to it at the bottom, passes over this hole, the LED glows depicting the activation of reed sensor and showcasing the usage of the path. The computation continues until unless the user reaches the end terminal. The latching

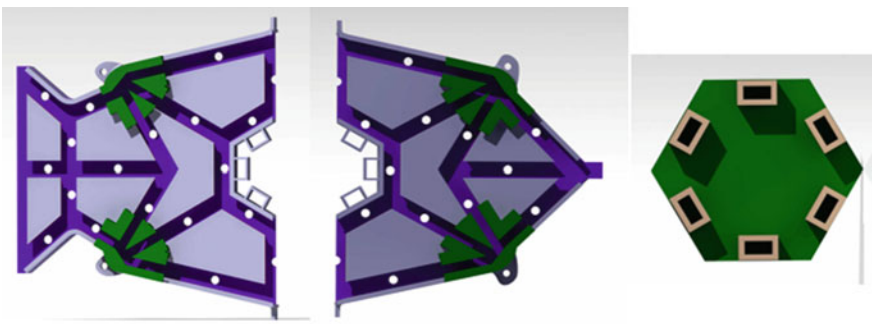

Fig. 60.4 3D virtual model of the components of the game board

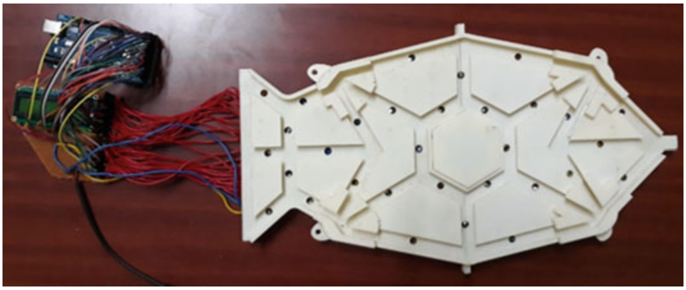

Fig. 60.5 RP-based game board prototype assembled with circuital system

circuit system helps in governing the total number of paths taken before reaching the end point. This further helps in evaluating whether the given number is attained by the user or not. After successful traversal, once the user reaches the end terminal, the display board displays whether the path taken is correct or not. The display board exhibits the value computed via the path taken and presents whether it is right or wrong.

How to Play?

The advancement with the board game needs to be carried taking certain rules and steps into consideration as mentioned below,

- The framework has three phases of design. The first phase, which is the left end, comprises of three vents. It is the starting end of the board game, which allows the player to begin choosing any one of the paths. It is mandatory to begin the game from this end only.
- These three vents open up to multiple pathways which goes through the second phase of design, having polygonal structures and curvaceous pathway for easy movement of the handle. This phase provides various options of traversal, hence provoking the player to activate the analytical mind. One cannot uplift or revert back or insert the handle from this phase. Repetition of any path once traversed is not allowed.
- The multiple pathways converge at the end of the frame to one narrow gateway which is the end terminal of the game. This terminal is the third phase of the design. Once the player reaches this end, the game ceases and results displayed.

60.4 Conclusion

The study clearly enlightens that children are capable of being design allies and play crucial role in enhancement of ideas and concept as put forth by Druin [7]. Sophisticated technology which appeals the children due to facilitation of

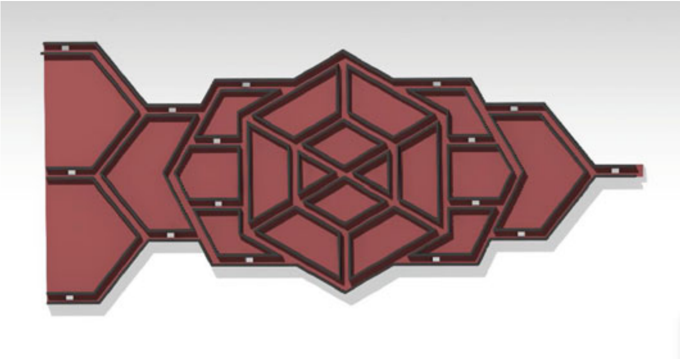

Fig. 60.6 Forecast of a game board for mall play zone

locomotive feature can never fully simulate the social world and can never approach the level of fidelity of interaction as put forth by Kass et al. [8]. In compliance with the study, the board game is designed for the age of 4–6 years and is also an effective tool for increasing the logical and analytical skills of children. A user-centric mechanism is chosen to develop a number-based board game. In aggregate, the current exploratory reviews lay the fundamental basis for analyzing how the number game could be scaled-up for utilization at a more broad level at schools, home, play zones, etc. Figure 60.6 clearly illustrates an instance of vertical board game suitable for gaming zone at malls. The outcomes demonstrate that a number board game when played individually can advance the numerical information of youthful youngsters. Another way to understand this esteem is to ponder the scientific idea you are attempting, recreate the probable pathways using analytical reasoning, and alter the diversion likewise. As the kids stay in play for a time period, the brain stays activated and cautious presenting kids to an outstanding diversion. Further, it has the benefit of advancing proficient learning, as kids are now acquainted with the fundamental components of the amusement.

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Chapter 61
A Study on Elderly Individuals' Attitude Towards ICTs

Aishwarya Pargaonkar, Wricha Mishra and Sudarshan Kadam

Abstract Due to increasing life expectancy, there has been an unprecedented increase in the population of elderly individuals (age 55 and above). Studies have revealed that the lifestyle of such elderly individuals has changed with the advent of information and communication technologies (ICTs). Though the use of ICTs by elderly individuals has elevated and it is widely perceived that elderly individuals have various potential benefits by the use of ICTs, they face barriers and challenges while adopting to newer technology. There is a difference in the need and ability of elderly individuals in the context of technology. Studies have revealed that elderly individuals have been overlooked during the development of products or services due to focus on younger adults as the main demography. This shift in demography has created a need to study the major factors that affect the usage and adoption of technology by elderly individuals which might help while designing technology and services for elderly. A modified questionnaire was administered on both the age groups: young-old (55–65 age) and old-old (65–75 age) (Age groups in american society and the rise of the young-old. Ann Am315 Acad Polit Soc Sci 415(1):187–198, 1974, [1]). The main objective of the study was to identify the factors that affect the use of ICTs by older adults and the barriers they face while adopting to technology.

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61.1 Introduction

61.1.1 Twenty-first Century Technology Versus Demographic Scenario

Technology enriches us which enables the creation of new opportunities in forms of social interaction, direct on-the-go access to information, constant availability and higher control of the surrounding environment. The impact of using advanced technologies has been very positive for the general population. Information and communication technologies (ICTs) have become an integral part of people's everyday lives wherein 'Information and Communication Technologies consist of the hardware, software, networks and media for collection, storage, processing, transmission and presentation of information (voice, data, text, images), as well as related services. ICTs can be divided into two components: information and communication infrastructure (ICI) which refers to physical telecommunications systems and networks (cellular, broadcast, cable, satellite, postal) and the services that utilise those (Internet, voice, mail, radio and television); information technology (IT) that refers to the hardware and software of information collection, storage, processing and presentation' [2]. The degree of usage of Internet and ownership of smartphones in India has increased in India in the second decade of the twenty-first century. Across developing countries, 54% of the population reported to be using Internet occasionally while 37% of the population reported owning a smartphone in 2015, which was a significant rise within two years compared to 45 and 21%, respectively, in 2013. In India, the number of people using Internet increased from 16% of the population in 2013 to 22% in 2015, while the number of smartphone users increased from 12% in 2013 to 17% in 2015 [3]. According to a report 'Internet in India 2017', published jointly by the Internet and Mobile Association of India and Kantar IMRB, as of December 2017, 481 million people were estimated to be using Internet in India with an Internet penetration of 35% of the total population. Though the Internet is widely acknowledged to be preserved for the youth (age 15–29 years), accounting for 60% of the total Internet users in India, the proportion of people using information and communication technologies (ICTs) over the age of 50 increased four times between 2013 and 2015 [4].

According to official population projection report for India (2001–2026), the life expectancy at birth for Indian male is projected to increase to 69.8 years and the Indian female is expected to live up to 72.3 years by 2021–2025 [5]. Due to increasing life expectancy, there has been an unprecedented increase in the population of elderly individuals. The elderly population (60 + years) comprised of 5.4% of the total population in India in 1950 and has increased to account for 9% of the total population in 2015. The population of elderly individuals of age 60 and above has grown from 20.3 million to 116 million in the years from 1950 to 2016 and is projected to rise up to 173.2 million in 2026 which would comprise 31.39% of the total population [5, 6]. Such population change trends pose challenges for many areas of society. This demographic shift requires different ways of dealing with health care, housing, transport, education, employment and product design.

The impact of using advanced technologies has been positive for the general population. Studies have revealed that the advent of ICTs has also had a positive impact on the lifestyle of disadvantaged groups such as elderly individuals. Previous studies have found that the use of ICTs by older adults can lead to a profusion of advantages. The advantages can be characterised to be resulting in opportunities for social interaction and self-discovery, increased access to information about current affairs and health information [7].

61.1.2 Technological Intervention for Older Adults

There exist factors which are responsible for the attitude of the elderly population towards technology. Elderly individuals' resistance to change and high cautiousness and hesitance before action compared to younger people have been documented by various psychologists and sociologist and have been revealed in various studies [8]. Therefore, as consumers too, older adults have found to be having the least level of adoption when it comes to new innovation or product. Studies have also found that the age is a factor to be negatively correlated to the attitude towards and use of technology of consumer [9]. This low adoption and resistance towards new technology shown by elderly deprive them of the benefits offered which could effectively positively change their lifestyle.

The penetration of presently widely accessible ICTs in the lives of today's elderly population happened at a later point of life as compared to younger generation. Younger generation were exposed to these technologies from birth or adolescence. Thus, there naturally exists a digital divide between these generations due to a lack of prior experience and training. Other reasons include economic restrictions and a large gulf between the attributes of technology and needs of older adults. Though the adoption rate of new technologies in older adults is less than that of younger adults [10], the willingness of older adults to adopt is more when the technology is useful and usable and when they feel self-adequate and self-efficient in using the technology. Previous studies have shown that the adoption of technology depends upon age-related concerns like decline in cognitive ability, decrease in memory capability and attention span, vision impairment, decreased motor control, technology-related like usability and efficiency of the technology as well as psychological factors like perceived self-efficacy and comfort in using technology and associated anxiety [11, 12]. Though the adoption of technology by older adults has seen a positive change in the twenty-first century, it is still not comparable to the rate of advancement of technology.

Due to the continuous increase of the elderly population in the world, designers should begin to consider this group and should take into account that new technologies could be designed that would significantly contribute to improving the quality of life of this population. The adoption of technology has been lagging in terms of designing for the elderly due to lack of understanding or existence of preconceived notion of the characteristics and abilities as well as the need and expectations of this segment of the population [13]. Elderly individuals have been overlooked during the development of products or services due to focus on younger adults as the main demography. During the whole process for designing products that are usable by the elderly, it is of importance that the unique needs and difference in abilities as compared to their younger counterparts are taken into account. For this purpose, it is essential to acquire or possess knowledge about and utilisation of correct methods that are effective for interaction with and data collection of the elderly. This data would allow the designer to empathise with elderly user to improve the efficiency and usability of the product with respect to their characteristics and expectations. This design process is known as the user-centred design (UCD). Very few literatures on traditional UCD provide enough guidance about methods that aim at involving the elderly user in designing process [14]. Current design processes are yet to consider important pain points such as motivation and context of the older adults' use of technology. Due to the lack of effective methods for proper assessment of older adults' needs, potential benefits that can be gained from this large demographic group are not realised [15–17]. Most of the previous studies regarding the use, perception and attitude towards technology were done on older adults between the age group 65 and above[x]. The old age can be categorised into young-old (55–75), old-old (75–85) and oldest-old (85). The 'young-old' represent the majority of older individuals who are relatively healthy, competent and satisfied with their life and remain engaged in a variety of activities in the society. The 'old-old' are those individuals who are frail, suffer from poor health and need medical attention, special care and other forms of support [1]. The age groups 'old-old' and 'oldest-old'(age 75 years and above) may not be as aware or as familiar to technology as older adults within the age group 55–65 due to exposure to technology by younger adults in the family, social influences and work-related advances in technology as most of older adults from this group are employed. Research on this age group has more potential opportunities. Thus for the purpose of this study, the age group considered was 'young-old'(55–75 years age) which was further divided into two groups named—young-old (55–65 age) and old-old (65 and above age).

Taking these factors into consideration, the overall aim of the current study is to identify the factors that affect the use of technology by older adults, their attitude towards new technology and the barriers faced by older adults in adopting new technologies and build on previous studies by investigating the perceptions of older adults towards technology. Also, the attitude of the elderly individuals, disparities in use and attitude towards technology between the age groups young-old (55–65 age) and old-old (65 and above age) of older adults are investigated in this study.

61.2 Methodology

The study was conducted on eighty-five elderly individuals in Pune, an urban city situated in the western part of India. The participants were divided into older elderly individuals (age ranging from 65 and above years) and younger elderly individuals (age ranging from 55–65 years). A questionnaire was compiled and from literature administered on thirty participants for pilot study. The results of pilot study revealed that the ICTs dominantly used by the participants were personal computers and smartphones; the pattern of usage was dominated by for the purpose of communication (instant messaging and video chat) and social media. Based on the results, the questionnaire was modified and administered further on sixty participants belonged to the young-old (55–65 years) category while twenty-five participants belonged to the old-old (65–75 years) category. The questionnaire included general questions to get demographic details, followed by questions quantifying the attitude of older adults towards technology on a Likert scale. Some questions were about subjective awareness and existing ICTs, perceived importance of technology in their life, willingness to learn new technology, self-efficacy, willingness to ask for assistance in learning new technology, willingness to invest time and money in technology they perceive to be useful, perceived feeling of security while using Internet, perceived feeling of enjoyment while using ICTs. The reliability of the questionnaire was evaluated by Cronbach's alpha. The Cronbach's alpha value was found to be 0.769 which is good [18]. Quantitative research approach was used. Statistical analysis was conducted in SPSS version 17.

61.3 Results

Table 61.1 provides the basic information about the respondents. 68.23% of respondents belonged to age 55–65 years and 31.73% belonged to the age group of 65 years above. To examine the association between the socio-demographical factors and the factors quantifying the subjective attitude of older adults towards technology, a two-tailed chi-square test of independence was performed. Significance level was set at $p < 0.05$.

The frequency of use of Internet was significantly correlated to age, gender, employment status of the respondent and obviously to the accessibility of ICTs. Awareness of prevalent ICTs was also significantly correlated to frequency of use of ICTs. The perceived importance of technology in life of older adults was correlated to the level of educational qualification, accessibility to ICTs and frequency of use of Internet. Factors relating to the attitude of older adults towards learning new technology were perceived willingness to learn, willingness in asking for assistance while learning, perceived self-efficacy in learning, perceived difficulty in learning due to age-related changes in health and willingness to invest time and money in new technology (Table 61.2).

Table 61.1 Basic information of participants

Characteristics		N	%
Age	55–65	58	68.23
	65+	27	31.76
Gender	Male	71	83.52
	Female	14	16.4
Education level	Lower than 12th	13	15.3
	Graduation	59	69.41
	Post-Graduation	13	15.3
	PhD	0	0
Employment status	Unemployed	7	8.23
	Employed	36	42.35
	Retired	41	48.23
Marital status	Unmarried	2	2.35
	Married	75	88.23
	Divorced	2	2.35
	Widowed	5	5.88
Annual income	Less than 0.2 M	11	12.9
	0.2 M–0.5 M	13	15.3
	0.5 M–0.7 M	37	43.52
	0.7 M–1 M	9	10.58
	More than 1 M	4	4.7

Table 61.2 Chi-square test results (1)

Factors	Sig. value*	Significantly correlated to
Frequency of use of internet	0.025	Age
	0.032	Gender
	0.000	Employment status of the respondent
	0.000	Accessibility of ICTs
Awareness of prevalent ICTs	0.001	Frequency of use of ICTs
The perceived importance of technology	0.002	Level of educational qualification
	0.013	Accessibility to ICTs
	0.002	Frequency of use of internet.

*Significant at $p < 0.05$

Willingness to invest time and money was significantly correlated to the perceived importance of technology, willingness to learn, household income and frequency of use of Internet. Perceived willingness to learn was significantly correlated to the perceived importance of technology, perceived self-efficacy in learning, perceived feeling of closeness to family and friends due to technology and age of the respondent. Perceived self-efficacy in learning new technology was

Table 61.3 Chi-square test results (2)

Factors	Sig. value*	Significantly correlated to
Willingness to invest time and money	0.001	Perceived importance of technology
	0.04	Willingness to learn
	0.025	Household income
	0.009	Frequency of use of internet
Perceived willingness to learn	0.038	Perceived importance of technology
	0.000	Perceived self-efficacy in learning
	0.000	Perceived feeling of closeness to family and friends due to technology
	0.006	Age of the respondent
Perceived self-efficacy in learning new technology	0.001	Willingness to ask assistance while learning
	0.001	Perceived difficulty in learning due to age-related changes in health
	0.042	Age of the respondent
	0.005	Number of young adults in the family and frequency of use of internet
Perceived difficulty in learning due to age-related changes in health	0.001	Willingness to ask assistance while learning

*Significant at $p < 0.05$

significantly correlated to willingness to ask assistance while learning, perceived difficulty in learning due to age-related changes in health, age of the respondent, number of young adults in the family and frequency of use of Internet. Perceived difficulty in learning due to age-related changes in health was significantly associated with willingness to ask assistance while learning. Factors related to social media were awareness about social media, perceived feeling of enjoyment while using social media, perceived feeling of security while using social media and perceived importance of social media (Tables 61.3 and 61.4).

The awareness of popular social media platforms was positively correlated to the level of educational qualification, perceived importance of technology, perceived self-efficacy in learning, willingness to invest time and money in new technology and frequency of use of Internet of the respondent. The perceived importance of social media was significantly correlated to perceived self-efficacy, level of education, household income and accessibility to ICTs. The perceived feeling of enjoyment while using social media was associated with the perceived feeling of self-efficacy while learning, willingness to invest time and money in technology, perceived feeling of security while using social media, frequency of use of Internet and level of education. To test the disparities in the attitude of technology between two groups, younger elderly individuals (55–65 age) and older elderly individuals (65 and above), Mann–Whitney test was performed. There was a significant difference in usage and attitude of these two groups towards technology (see Table 61.5).

Table 61.4 Chi-square test results (3)

Factors	Sig. value*	Significantly correlated to
The awareness of popular social media platforms	0.014	Level of educational qualification
	0.000	Perceived importance of technology
	0.014	Perceived self-efficacy in learning
	0.001	Willingness to invest time and money in new technology
	0.003	Frequency of use of internet of the respondent
The perceived importance of social media	0.002	To perceived self-efficacy
	0.001	Level of education
	0.008	Household income
	0.003	Accessibility to ICTs
The perceived feeling of enjoyment while using social media	0.003	The perceived feeling of self-efficacy while learning
	0.001	Willingness to invest time and money in technology
	0.000	Perceived feeling of security while using social media
	0.000	Frequency of use of internet
	0.021	Level of education

*Significant at $p < 0.05$

Table 61.5 Mann–Whitney test between age groups: younger elderly (55–65) and older elderly (65 and above)

	Mann–Whitney U	Z	Asymp. Sig. (2-tailed)
Perceived importance of technology in life	612.500	−1.567	0.117**
Willing to learn new technology	634.500	−1.366	0.172**
Perceived self-efficacy in learning new technology	358.500	−4.029	0.000*
Willingness to ask for assistance while learning new technology	726.500	−0.439	0.660**
Willingness to invest time in technology perceived to be useful	510.000	−2.637	0.008*
Willingness to invest money in technology perceived to be useful	452.500	−3.143	0.002*
Perceived difficulty in learning new technology due to age-related health concern	534.500	−2.110	0.035*

(continued)

Table 61.5 (continued)

	Mann–Whitney U	Z	Asymp. Sig. (2-tailed)
Awareness about existing popular social media platforms	459.500	−3.099	0.002*
Perceived feeling of security while using social media platforms	394.000	−3.763	0.000*
Perceived feeling of enjoyment while using social media platforms	283.500	−4.794	0.000*
Perceived importance of social media	583.000	−1.858	0.063**
Perceived feeling of closeness to family and friends due to ICTs	756.000	−0.135	0.892**
Perceived feeling of security while doing online money transactions	447.000	−2.043	0.041*

*Significant at level $p < 0.05$
** Not significant

61.4 Conclusion

The study revealed that most of the respondents had access to personal computer (61.6%) and smartphones (89.3%); 83.5% of the respondents have access to Internet of which 46.4% use Internet daily and 26.2% are always connected to Internet. The context of use of ICTs by older adults ranges from communication (instant messaging, calls, video calls) to government administrative work. Majority of the respondents use ICTs for the purpose of communication (79.1%) and entertainment (72.1%); 61.6% of the respondents are active social media. These results are in consensus with previous reports which have conferred that Indians have shown a significant rise in the usage of digital media through personal computers and smartphones. Thus, accessibility of ICTs to the older adults doesn't seem to be a barrier for usage of technology by them.

The present study identified the comprehensive list of all factors that affect the use of technology by older adults and their attitude towards new technology which was found to have been reported in literatures as casual factors for restricting them towards ICT's usage. The dominant factors identified were as follows: awareness about existing ICTs, perceived importance of technology in their life, willingness to learn new technology, self-efficacy, willingness to ask for assistance in learning new technology, willingness to invest time and money in technology they perceive to be useful, perceived feeling of security while using Internet and perceived feeling of enjoyment while using ICTs. Subsequently, the study deciphered the relationship (chi-square test) between the causal factors for both older and younger adults. Then in order to quantify the disparity in attitudes between older and younger adults, Mann–Whitney test was computed. The results showed that perceived self-efficacy in learning new technology, willingness to invest time in technology perceived to be useful, willingness to invest money in technology perceived to be useful, perceived difficulty in learning new technology due to age-related health concern, awareness about existing popular social media platforms, perceived feeling of security while using social media platforms and perceived feeling of enjoyment while using social media platforms had significant difference in both groups.

61.5 Discussion

Due to increasing life expectancy, there has been an unprecedented increase in the population of elderly individuals (age 55 and above). Studies have revealed that the lifestyle of such elderly individuals has changed with the advent of information and communication technologies (ICTs). Though the use of ICTs by elderly individuals has elevated and it is widely perceived that elderly individuals have various potential benefits by the use of ICTs, they face barriers and challenges while adopting to newer technology. There is a difference in the need and ability of elderly individuals in the context of technology. Thus, it is relevant to explore the usage of ICTs by older adults.

Many studies have revealed that one of the reasons for slow adoption and therefore barrier to usage thereof older adults is lack of training. Older people recognise that they have difficulty in learning new technology as perceived difficulty in learning new technology due to age-related health issues (vision impairment, slowing of cognitive process, decreased memory capability, decreased attention control, decreased motor control) was significantly correlated to the perceived self-efficacy while learning new technology. Most of the respondents (72%) showed a willingness to learn new technologies. Many studies have shown that social isolation of older adults can be overcome by the use of ICTs. The willingness to learn new technology was associated with the perceived feeling of closeness to family and friends due to the use of technology. This could be a motivational factor for older adults' usage of technology. The willingness to learn new technology was also associated with age, importance of technology and feeling of security while using social media. Thus, feeling security could be a potential barrier for usage of technology by older adults. Perceived feeling of self-efficacy was associated with age, willingness to learn new technology, willingness to ask for assistance and number of young adults in the family. A presence of a supportive environment helps positively influence the attitude of older adults towards technology and help motivate them to learn and explore new technology.

The present study is a comprehensive study which has identified all the factors from literature impacting usage of ICTs on elderly individuals. Furthermore, the study identified the significant factors impacting usage of ICTs on both young-old (55–65 age) and old-old (65 and above age). The study also attempted to show the disparity in attitudes of young-old (55–65 age) and old-old (65 and above age) towards ICTs. Literature review revealed that most studies did not distinguish the 'elderly' into subdivisions as we have subdivided them into which are likely to have differences in perception of technology. Many studies have studied the digital divide between young adults and older adults [19]. We studied if the demographic shift in the twenty-first century and the increase in the use of technology has created digital disparities between two age groups within the population firstly, the young elderly individuals (55–65 age) and older elderly individuals (65 and above age). It was found that age group 1—younger elderly (55–65 age) had more positive attitude towards technology than age group 2—older elderly (65 and above age). Age group 1 (55–65 years) seem to have coped up better with the advances in ICTs, and there is a presence of digital divide between age group 1 and age group 2. Age group 1 are more motivated and confident in learning new technology, though both age groups are equally willing to learn new technology and ask for assistance while learning new technology. Also, they are more willing to invest time and money in learning new technology if they perceive it to be useful. There was a difference in self-efficacy and perceived difficulty in learning new technology due to age-related health concerns between the age groups. While both groups have acknowledged the importance of technology in the twenty-first century, there is a difference in feeling of security while using technology.

Hence, when designing universally the elderly should not simply be considered a single division based on age but should be divided into subdivisions as these distinctions provide significant insights regarding their varied perception of ICTs. Current design standards and user research distinguish between young and old adults as stated earlier, while our study shows that a similar divide exists within the elderly adults as well. Hence, there is a scope of developing new design standards and user research guidelines which consider the younger subdivision of the elderly as not separate from young adults owing to their attitude towards ICTs, while considering that this group might be more closely related to young adults than the older subdivision of the elderly.

61.6 Limitations

Our findings are based on a survey of 84 participants, though the sample size is commensurate to the survey approach, only 14 women participated in the survey. We acknowledge this disparity and the fact that our findings may not reflect the perspective of the entire older population. Also, the participants resided in a metropolitan area of western India, the experience of our participants may be substantially different from those older adults living in underdeveloped parts of the world or developed Western countries.

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Chapter 62
User Interfaces for Safety Inspections in Underground Mining

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Abstract Technology has made inroads in various domains of the economic industry and the Mining Industry is one such realm which has undergone a substantial transformation in a bid to attuning to the demands of modernity. Digitization of Mines is a relatively new aspect of mining, wherein the use of technology holds the potential power to revolutionize the mining experience. This has led to the emergence of new vocabularies that is in juxtaposition with the old while creating challenges that were unforeseen before the foray of technology. This, however, presents a new perspective towards the creation of user-centred designs that would require design specifications unique to the users, i.e. the mining operators. The extremely hazardous work environments of underground mines make it imperative that safety comes first. Thus safety and compliance go hand in hand and are of utmost importance. The task of a mining operator starts with an inspection of their mining equipment underground as per safety regulations of the mine. The task is carried out in the dark underground environment via a paper-based checklist. This however leaves room for error while making the task laborious and tedious. With digitization, this process has undergone a tremendous change by enhancing the task of inspection without complying safety. There are however no frameworks for interface design specific to underground dark environments that these mining operators work in. This created an opportunity to come up with guidelines for designing UI for underground mining equipment checklists. Through extensive focus group studies, user interviews and user journey mapping, design guidelines were formulated which focused on UI elements, colour contrast and eye adaptation for such settings. These guidelines were further tested and evaluated with the user groups. This paper will discuss the findings and implications of this research.

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62.1 Introduction

62.1.1 Existing Scenario and Technological Interventions

Underground mining comes with its own set of operational hazards pertaining to working in dark environments, strenuous navigation within the deep underground mine, communication challenges via radio, etc. which are just to name a few. Mining operators often get disoriented and lose their way inside the mines. In the event of any health hazard or mishap or repairs, due to the present drawbacks of communication over radio, miners frequently face delays while reporting such incidents. These are some of the glaring concerns which have been plaguing the Mining industry and thus have paved its path towards digitization. Hence mining companies are working on various strategies for enhancing mobility and connection via use of wireless technologies in their mines for increased worker safety and optimized production [1].

With the boom of the economy, an ever-increasing consumer market has gained foothold in the mining companies' profitability and sustainability in recent years [2]. As with most scenarios concerned with this volatile economy, the future of its impact is unforeseen even though at present, the changing global market has transformed mining operations and its business priorities. The key concerns for mining companies today are maximizing yield recoveries by focusing their operational investments on such areas and improving efficiency at the same time while still satisfying regulatory requirements and maintaining safe or 'zero harm' working environments. That is a tall order for mining companies combined with the lack of skilled workers which greatly limits their operations to meet the demands of this global market. Hence, connected or 'smart' operations can prove to be a silver lining for the mining industry [2]. With greater connectivity and seamless information sharing, mining companies can better understand their operations, improve their performance and reduce risks. At present however most mining companies lack the connectivity and embedded intelligence which are imperative for the smooth operation and future growth, scalability and expansion of mines. Thus, with digitization, companies can now incorporate new systems and technologies and provide the imperative facelift to mining operations.

Safety is enhanced by manifold when a mine is connected. With technologies like RFID tags and wireless technology, operation of tasks gets more streamlined and convenient. Such induction of technology can help mine managers to not only keep track of the number of miners working underground but can also help identify any kind of mishaps immediately. Apart from that, use of other technologies such as video camera, voice and display technologies connected to a network can be used to monitor and communicate with employees in case any safety incident should occur. Wireless cameras, digital media signage systems can deliver safety warnings or emergency instructions to workers [2]. Thus, in other words, mining industry can benefit greatly from digitization as its impact is twofolds: (a) it can aid in the quick identification and implementation in any accident and (b) the ability to collect and analyse data surrounding such safety-related events can help in the better understanding and identifying the factors that lead to such incidents. Based on this, mining companies can adjust their processes or safety training can be refined as per the requirements.

This shift towards digitization presents new opportunities to rethink strategies, unlock new productivity resources, improve sustainability, close functional gaps and interact with key stakeholders in innovative ways [3]. Mining operations would be required to undergo a major cultural shift on their path to digitization to especially improve equipment utilization, workforce utilization, real-time production streamlining and for improving workplace safety [3]. In this regard, many consultancies and companies are offering technological solutions and consultation services to digitize mines. However, there is no specific structure pertaining to the process of transition into digitization. This paper will explore the aspects of digitization of underground mines to understand the role that design can play for better operationalization and safety features in mines in extreme dark underground environments. As there are no frameworks for interface design specific to underground dark environments, this paper will explore the formulation of guidelines for designing UI for underground mining equipment checklists. An underground gold mine in the USA was visited to observe the scope and gaps for digitizing an underground gold mine.

62.2 Workplace Safety in Underground Mines

Considering the hazardous working environment of underground mines, safety is one of the foremost concerns. The USA Govt. has regulations on workplace safety which is governed by Mine Safety and Health Administration (MSHA) [4]. MSHA's regulation defines few safety inspections which should be conducted on a daily basis. Workplace inspection and equipment inspection are two of the most important inspections that need to be carried out every day, every time before a task is carried out in the mine. MSHA also conducts on-site inspections of the mines four times a year for health and safety compliance and to ensure that these regulations are being followed fastidiously in the mines. When such an inspection by the MSHA takes place, the mine management is required to produce one year of inspection data for evaluation and further instructions from MSHA henceforth.

62.2.1 MSHA and Mining Safety Guidelines

Workplace inspection regulation act [5] and equipment pre-ops regulation act [6] are two such acts by MSHA and Govt. of the USA, which are to be strictly followed by the mines on a daily basis.

62.2.2 Workplace Inspection Regulation Act

Workplace Inspection: An inspection carried out to ensure safety in Miner's place of work. Falling rocks, poor ventilation, chemical leakage, broken roads, etc. are few of the hazards when it comes to a workplace.

The workplace inspection regulation act states that [5]:

(a) A person designated by the mine operator is to examine each workplace at least once per shift before work commences to check for conditions affecting miner's safety or health.

   1. The operator is to notify miners in any affected areas or conditions that might affect their safety or health and promptly take required actions for mitigation of such conditions.
   2. The person designated by the operator for inspection is to report any imminent danger and bring it to the attention of the operator in charge.

(b) A record containing the name of the person conducting the examination, date of the examination, location of all areas examined and description of each condition found that may adversely affect the safety and health of the miners is to be recorded before the end of the shift for which the examination was conducted.
(c) When a condition that may adversely affect safety or health is not corrected promptly, the examination record is to include the date of the corrective action.
(d) The records are to be maintained for a year by the operator and be made available for inspection by authorized representatives of the Secretary and the representatives of miners.

62.2.3 Equipment Pre-Ops Regulation Act

Equipment Inspection: An inspection which is carried out to ensure that equipment like haul truck, loader, bolter, driller, etc. are in good health to conduct mining operations.

The equipment pre-ops regulation act states that [6]:

(a) Self-propelled mobile equipment is to be inspected by the equipment operator before being placed in operation for a work shift.
(b) Defects on any equipment, machinery, and tools that affect safety are to be corrected in a timely manner to prevent accidents.
(c) When defective items or equipment make continued operation hazardous to persons, they are to be taken out of service and marked or tagged prohibiting further use until the defects are corrected.

(d) Any kind of defects on equipment affecting safety, which are not corrected immediately, are to be reported to and recorded by the mine operator. The records are to be maintained and made available for inspection by authorized representative of the Secretary.

62.3 Methodology

An underground gold mine in the USA was visited to observe the opportunities and challenges for digitization. Site visits were undertaken while being accompanied by the mining operators during their work shifts. This provided ample insights and aided extensively in the understanding of underground mining operations. Data were collected from the observer's point of view through videos and photographs. Agile UX methodology was followed keeping in mind the various stakeholders involved and the flexibility in addressing issues that was required by this relatively new domain of mining. A user focus group was selected which comprised of the mining operators working in the gold mine apart from internal and external stakeholders. Design concepts and ideas were shared through low and high fidelity mock-ups. The user focus group was involved in every step of the design process and their role was crucial in evaluating the proposals put forth by the design team. This paper undertakes the case study-based model combined with extensive focus group studies, user interviews and user journey mapping. Design guidelines were formulated which focused on UI elements, colour contrast and eye adaptation for such settings. These guidelines were further tested and evaluated with the user groups. This paper will discuss the findings and implications of this research.

62.4 Case Study

62.4.1 Current Practices

As observed on visits to the underground gold mine in the USA, mine operators use paper cards of dimension 15 cm × 8 cm to perform their various inspection tasks manually. These paper cards usually contain a checklist of total of 30–40 inspection points per card. These cards are colour coded based on the type of task carried out and are used for both workplace and mining equipment inspection. These checklists are printed in black with card colour variations for each specific task. Mining operators carry out the inspections by filling up the checklist which contains the options of 'it's okay' or 'it's not okay' against each checkpoint.

62.4.2 Design Drawbacks

In underground extreme dark environment, legibility is one of the foremost issues. Safety of miners is the backbone of mining operations and the job of inspection requires utmost attention of the task at hand. As the mining operators have to carry out their operations in such setting keeping in mind the safety of miners at stake, they undergo extreme work environment stress while carrying out inspection through the paper-based cards. These cards containing almost 40 items are hardly legible as the font used are relatively small. The task gets more arduous as the only source of light is the headlamp on their safety caps. As the text size is quite small to accommodate all the items for inspection, the mining operators have to hold the paper cards very close to their eyes to focus the light on the text while filling up the checklist. This can lead to a hazardous scenario even with a mere mistake while the task of completing the checklist is carried out. Apart from this, paper cards present the issue of maintaining a log of hundreds and thousands of paper-based records throughout a year. As the MSHA inspects the mines four times a year, it becomes a cumbersome task to present all the records of the past for their inspection. This results in a lag in real-time communication. Paper cards can also be confusing for a novice as there are various colour codes specific to the tasks besides the legibility issues of using black ink on colour cards in dark environments. There is also the issue of carrying these stacks of cards underground every day for their inspection job. As observed on the site visits, a portion of the miners is colourblind due to the work environments they are in. The present practice of paper-based colour cards does not address this issue.

62.5 Design Process—Agile Methodology

Agile Methodology grew out of programmer's attempts to solve common pain points experienced during software development projects and is mostly focused on developers [7]. Hence its foray into UX design is still at its nascent stage. This methodology comes with a lot of benefits such as an incremental approach, flexibility to change direction based on customer and stakeholder feedback within short timeframes [7]. Under this development process, simultaneous work can be carried out by an entire team on the same elements of a project which results in realization of the project swiftly through smaller goals while keeping in mind the bigger context for consistent user-centred designs [7]. This methodology was applied for the development of the design process as it takes into account the qualitative insights apart from the quantitative insights while providing the flexibility to take into account different types of data from the users.

62.6 Design Approach

62.6.1 Software Application for Conducting Inspections

The design solution towards the digitization of the task of inspection in the underground gold mine was realized in the form of an app. A 9.7-inch tablet was provided to the miners in which they could access this app through which inspections could be done. An option of mounting the tablet to the equipment's dashboard was also provided. This app is a real-time app which stored the inspection records in a cloud server which could be accessed at any time. The app creates tasks to conduct workplace and equipment inspections on a daily basis. Operator logs in using a unique login id and password to access the app. Inspections are displayed on the screen of the app as tasks. Inspections typically contain 30 points with the options of OK, NOT OKAY and CORRECTED against which the operator has to check to complete his task.

A dark themed layout was designed in order to accommodate the needs of an Underground mine environment. The app visualized the tasks as scrollable inspection items. It was observed during the site visits that every operator has a unique pattern of inspection when it comes to workplace or equipment inspection. While performing the equipment inspection, few started from the interior of the equipment, few started from exterior of the equipment. Left to right and right to left inspection patterns were also observed in the mining operator's behaviour. But most commonly, Mining operators have a tendency to report errors first and fill out the rest later. This observation presented the option of incorporating all the items in a scrollable page and letting the users report errors first and fill the rest later. This pattern of filling inspection forms is synonymous to that of filling a paper-based inspection card using a pencil while doing away with the cumbersomeness of the previous practice.

While designing the UI, references from "Web content accessibility guidelines 2.0" by W3C were referred to and these criteria were adopted for formulating the design guidelines [8]. W3C has standard content for web accessibility.

Linear sequence: A linear sequence of inspection items is rendered so that user can make sense of the content and its relevant action. This improves accessibility
Colour: Colour is one of the key aspects for accessing the information. Few mining operators have colour deficiencies. Whereas, few of the aged mining operators have partial sightedness. Darker colour scheme was used in the design which would aid the user's eye to adapt to the dark underground environment. Text was integrated into the design as much as possible to mitigate risk of distinguishing between colours. Keeping in mind that few of the miners were colour blind, a monochromatic colour scheme which helps all types of colour blind people was used in the design. Colour Analyser tool, to check design feasibility for colour blind people was used extensively while creating the designs [9].

Elements of Interface	Size/Height in pixels	Text Size	Ideal Contrast Ratio	Actual Contrast Ratio
Inspection item text	20	Large (AAA)	4.5:1	5.46:1
Top Bar text	20	Large (AAA)	4.5:1	5.72:1
Headline text	20	Large (AAA)	4.5:1	6.26:1
Buttons in Top bar	48	Large (AAA)	4.5:1	5.72:1
Action Buttons: Not selected	48	Large (AAA)	4.5:1	5.46:1
Action Buttons: Selected	48	Large (AAA)	4.5:1	5.46:1

Fig. 62.1 Colour contrast ratio (minimum)

Elements of Interface	Size/Height in pixels	Text Size	Ideal Contrast Ratio	Actual Contrast Ratio
Inspection item text	20	Large (AAA)	7:1	9.79:1
Top Bar text	20	Large (AAA)	7:1	9.38:1
Headline text	20	Large (AAA)	7:1	10.12:1
Buttons in Top bar	48	Large (AAA)	7:1	9.38:1
Action Buttons: Not selected	48	Large (AAA)	7:1	9.79:1
Action Buttons: Selected	48	Large (AAA)	7:1	9.79:1

Fig. 62.2 Colour contrast ratio (enhanced)

Contrast: To accommodate user of all types of vision, two versions of interfaces were designed-one with minimum contrast and one with enhanced contrast. Minimum contrast interfaces with a ratio of greater than 4.5:1 was used which helps users with 20/20 and 20/40 vision [10]. Whereas, enhanced contrast interfaces with contrast ratio of greater than 7:1 were used which helps elderly users and users with visual deficiencies with 20/80 vision [11]. A UI Style switcher was provided in order to switch between the minimum and enhanced UI contrasts [12]. User can seamlessly switch between these two UIs from the settings of the app. Colour contrast ratios used for both the UI styles are given in below figure. Contrast analyser tool was used to test proper contrast ratio (Figs. 62.1 and 62.2).

Visual presentation: Level AAA sized elements were used in order to emphasize the content in the layout. Mechanism of extra line spacing was used to emphasize a row which contains inspection item. Bigger action buttons were provided in order to create visual impact. This improved the accessibility of content within a page (Figs. 62.3 and 62.4).

All the designs were tested as per Agile Methodology with the user group of 15 people to ensure quality of the design application.

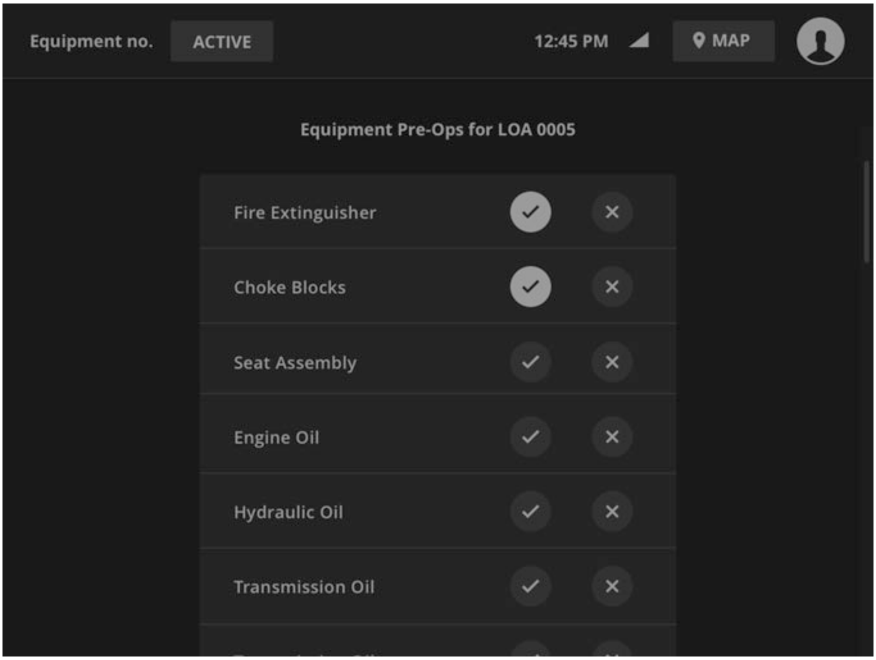

Fig. 62.3 Minimum contrast interface

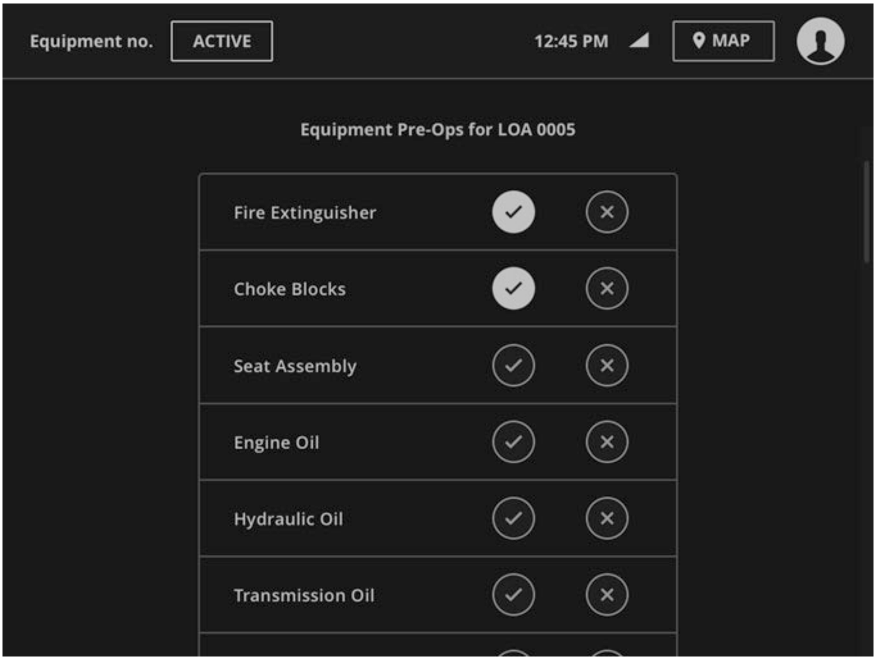

Fig. 62.4 Enhanced contrast interface

62.7 Conclusion

This research is a foray into the new domain of digitization of underground mines. Hence, the research work is far from complete but can be considered as a small step towards this field. The guidelines formulated through this research can aid designers in future work that could be taken up in this ever-evolving scenario of digitization. Further intensive research in the field of user patterns, eye tracking can be taken up to refine the user interfaces for safety inspections in underground mining.

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Chapter 63
User Expectations of Augmented Reality Experience in Indian School Education

Pratiti Sarkar and Jayesh S. Pillai

Abstract Emerging technologies are lately being welcomed in Indian schools to enrich the quality of teaching and learning. Augmented Reality (AR) is one such technology that can be introduced in the classrooms. For a fruitful acceptance, it is required to design the AR interactions in schools as per the expectations of students, teachers and parents for a satisfactory user experience. In this paper, we present our study that was conducted with 47 participants belonging to three user groups of 6 parents, 7 teachers and 34 students. The broad goal was to understand the outlook of students toward technology as well as the expectations of the three user groups from an AR experience in Indian school education. Based on the mapping of the user stories, certain inferences were obtained which suggested the user requirements pertaining to AR experience in classrooms. We posit that these characteristic expectations of user experience can be used to develop AR applications for classrooms in future.

63.1 Introduction

With the accelerating pace of evolution of technology, many schools in India are adopting different technologies to enhance the learning experience of students. From projector screens to interactive whiteboards, from online learning management system to introduction of Virtual Reality (VR) cardboards, there are various technology trends that have been accepted and are used in India and worldwide. One such technology is Augmented Reality (AR). With the help of AR, computer-generated graphics can now be superimposed on to the real world in

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one's field of view. Certain aspects of AR such as superimposing vector graphics, concept visualization, annotations, virtual instructions and X-ray vision [1] can be used in present classroom scenarios to provide an interactive and spatial learning experience.

In education, various stakeholders are involved in the making of an efficacious institution. Teachers, students and their parents are among the top-level entities who hold certain expectations from the services provided in the schools for effective learning of the students. With the advent of technology inside and outside classrooms, it has become quite essential to provide a satisfactory user experience to these user groups, for which it is required to meet their expectations. Based on the prior expectations of the end users, the experience of using a service or product can be enhanced further. Hence, to bring up the use of AR applications in classrooms, it is required to study the expectations of these user groups to provide them an enriching user experience and enhanced learning of the students.

We thus sought to investigate the expectations that the different user groups may have toward the experience of using AR in classrooms in future for the students. For this purpose, we interviewed few parents, teachers and students of different standards to get a varied range of opinions. This study is broadly aimed at identifying the characteristics of user expectations that can be used to develop AR applications for classrooms in future to satisfy the learning experience of students.

63.2 Background

63.2.1 Technology Trends in Indian Schools

The advent of technology is evident enough in many sectors. Education being one of these sectors, various technologies across the world have been used to bring an impact in the way of teaching and learning. In many schools in India, the traditional method of blackboard teaching is now getting supported/replaced with several digital means. Simple blackboards are now getting replaced with interactive whiteboards where online shared contents (images, videos, audios, animations, etc.) can be projected and explained simultaneously [2]. Several schools are providing digital devices like tablets, laptops, desktops etc., to the students to help them learn advance concepts through online modules [3]. It also helps parents and teachers to regularly monitor the students' performance. Several mobile applications are also being used as a means of practice modules [4]. Thus, rapid acceptance of technology is now being observed in and reported by many schools in India where the students are being encouraged to enhance their learning skills.

63.2.2 Augmented Reality (AR) Technology in Education

Augmented Reality (AR) technology is one of the emerging technologies which interactively combine the virtually generated computer graphics on to the live scenario in real time [1]. AR experience can be obtained using immersive AR glasses or on a mobile device [5] where the device's camera first scans the environment to map the spatial information and tracks back in real time to superimpose the related virtual data onto the real surrounding [6]. Due to the different advantages of AR like overlaying vector graphics, display of virtual instructions, annotations, visualization of concepts, X-ray vision of human body parts etc., researchers have suggested various domains of application of AR including education and learning, medical, manufacturing and repair, entertainment, etc. [1, 7, 8].

With the help of AR technology, teachers and students can do lab experiments and activities safely and securely which are otherwise not advised to do in classrooms [3]. This is possible due to the interactive overlays of virtual objects on to the real world. Hence, applications of AR can be majorly seen in Science [9], Mathematics (Geometry) [10] and Humanities [11] where complex and abstract concepts can be effectively taught in AR [12]. Some studies have reported the advantage of AR in motivating and enhancing the performance of learning [13]. With the help of AR, students are also able to learn in collaboration [14]. However, the challenge comes in the way of introducing AR in the course content. Thus, it is required to see how the teachers, students and parents look forward to the acceptance of the working of AR in classrooms.

63.2.3 User Expectation and User Experience

The increase in use of mobile- and web-based applications necessitates the need for providing intuitive and flawless interaction to the end users. This leads to the users anticipating a consistency across all interfaces. According to ISO, user experience (UX) is defined as "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service." The manner of perceiving the use of an interface by the user depends on the three levels of user expectation [15]: (1) entrenched expectations: formed in the mind's subconscious due to the use of multiple similar interfaces over a long time period; (2) formative expectations: formed due to the experience of a particular aspect; (3) on-off expectations: formed at the very moment the user sees an interface. To provide a satisfactory user experience, it would be required to meet the maximum possible expectations in all three levels. Thus, user-centered design can be obtained by knowing the target user well and their prior experiences. The user experience with the emerging technologies plays a key role in their successful acceptance. Work by Olsson et al. [16, 17] has been done to evaluate the user expectations from mobile Augmented

Reality in different contexts. To further evaluate their work in the field of education, it is required to understand the user expectations from AR interactions to provide a satisfactory user experience while learning.

63.3 Research Methodology

On the lines of the work done by Olsson et al. [16, 17], the research questions that we are addressing in our study in the context of education are as follows:

RQ1: What is the outlook of students toward technology?
RQ2: What are the characteristic user expectations of Augmented Reality experience in Indian school education?

63.3.1 Participants

We conducted the study with 47 participants who belonged to three different user groups—parents (6), teachers (7) and students (34). We performed convenience sampling for both parents and teachers and random sampling for students. Six parents who were there in the mall along with their children, experiencing the AR display put up there, were interviewed.

The teachers belonged to a private school and had been using one of the smartclass solutions—interactive smartboards in the classroom, along with the regular textbook teaching. Seven teachers teaching students of standards 6–10 were interviewed. Each taught a different subject—English, Mathematics, Geography, History, Biology, Physics and Chemistry. All of these teachers were using smartphones out of which three at times were referred to other educational applications complementing their teaching style.

The third user group was that of 34 students of a private school from standards 4–9, where 17 were male students and rest 17 were female students. These students are regularly taught using smartboards. Four students from standard 4 and six students each from standards 5–9 were interviewed in groups. Their individual responses to the interview questions were recorded.

Our aim was to come up with the characteristics of expected user experience to develop AR interactions for students in classrooms in future.

63.3.2 Procedure of Study

The exploratory study was conducted in two metropolitan cities of India and in three phases with three different user groups. The first user group was that of parents who were interviewed at a mall in Mumbai, India, where the visitors could get the experience of the AR display on a huge screen placed at some height.

The parents who were there with their kids to get the AR experience were interviewed with their consent, there and then in that environment. All these parents were unaware of the name of the technology that they were experiencing. They were therefore first explained about the technology and then given certain educational scenarios. To answer RQ2, their views on the AR technology use in those scenarios were then audio and video recorded.

The second user group was that of the school teachers from a school in Delhi, India. The teachers were interviewed individually. In the contextual interview, they were first asked about their acquaintance level with the current smartclass solution they were using in the classrooms and other educational applications. This was followed by giving them an introduction about the AR technology and showing a demo of the same using an existing AR-based mobile application. They were then given the similar educational scenarios in classrooms, and their expectations from the use of AR technology in these scenarios were audio recorded and logged to answer RQ2.

The students belonged to the same school. The students of each standard were interviewed in groups of 4–6 as limited time was available to interview them in the school. Each group of students was made to sit in a round table in an empty classroom. To address RQ1, they were first asked turn by turn, general questions on demographics and their outlook toward technology. They were then given introduction to AR technology and demo of some existing AR educational applications. Four students of higher classes were familiar with AR technology but had not explored any AR-based mobile application before. To address RQ2, based on their understanding of AR, they were encouraged to "think aloud" about their expectations of using AR in the classroom as per the suggested scenarios. They were allowed to give vague and highly futuristic responses. Responses from each group session, conducted for 50–70 min, were logged and video recorded.

63.3.3 Data Source and Instruments

The instruments used in the study included:

Contextual Interviews. The interviews were conducted in two phases. The first phase involved general questions based on the demographics, acquaintance with current technologies and any existing knowledge about AR. This was followed by a demo of an AR-based mobile educational application. The second phase of interview, conducted post-demo, involved questions about their understanding of AR and their expectations of using AR interactions in classrooms in various educational scenarios. In these interviews, participants were encouraged to "think aloud" while suggesting their expected user experience of using AR in future in classroom education. These interviews were audio and/or video recorded.

Observation Log. This comprised of a detailed log of responses of each participant in the two phases of interviews. Observations during the first phase included the responses given to the demographic questions and familiarity with common technologies and mobile applications. The log for the second phase consisted of responses of their views and expectations of using AR in classroom scenario.

63.3.4 Data Analysis

To address the research questions, we analyzed the qualitative data obtained from the interviews and observations. The data sources used were the audio–video recordings and observation logs of the responses during the interviews. The log data was used to answer RQ1. For RQ2, the audio–video recordings were transcribed to obtain the user stories. The user stories from all the three user groups were jotted down on sticky notes as it is. Using affinity mapping in multiple levels, the user stories were grouped further and brought down to certain themes. Inter-rater validity was performed by two researchers on the themes generated. Based on the mapping, certain inferences were obtained which suggested some characteristics of expectations pertaining to AR experience in classrooms.

63.4 Results

A. **Results related to outlook of students toward technology**

To answer RQ1, semi-structured interview was conducted with the students where their responses were logged for the questions pertaining to their attitude toward technology. Figure 63.1 summarizes the responses of the 34 students of classes 4–9.

All these students were exposed to the use of smartboard in class. As can be seen from the graph (Fig. 63.1), most of the students used smartphones to play games. It was observed that the students were very rarely using any additional educational application at home. Only 11 participants out of 34 (32.3%) were using an educational application for practice purposes. As the class standard increased, more students were using WhatsApp [18] on their own and had class-related discussions on different WhatsApp groups. They also had their own accounts in one or more social media applications. When asked about the popular AR-based game PokemonGo [19], 44.1% of the participating students had heard about or played the game. However, only four students of classes 8 and 9 knew what AR is, but they had not played the game or had not used any other AR-based application.

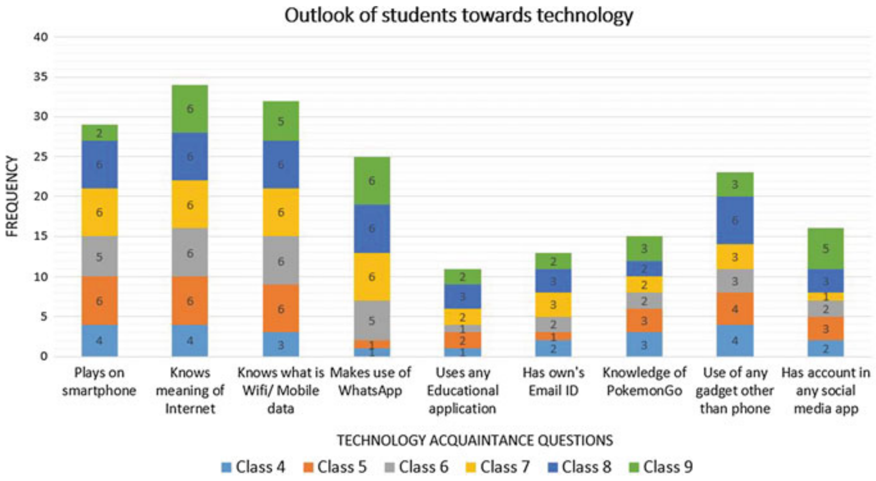

Fig. 63.1 Responses of students on their outlook toward technology

B. **Results related to characteristics of expected AR experience in schools**

Through affinity mapping of the user stories, valuable insights were obtained on the way the user groups perceived the AR experience in schools in future. The themes obtained from affinity mapping were then categorized under the three dimensions of learning given by Knud Illeris [20]: (1) *Content*—focuses on what is learned to develop one's functionality; (2) *Incentive*—focuses on maintaining the mental balance to develop one's sensitivity toward learning; and (3) *Interaction*—focuses on the interaction of content and incentive to help in one's integration into society. Thus, the description of 12 characteristics of expected AR experience in school, based on the themes generated under the three dimensions of learning, has been summarized in Table 63.1.

63.5 Discussion

Olsson et al. [16, 17] had considered the scenario of shopping to find out the expected user experience of mobile Augmented Reality services. Drawn from this work, our study has been done in the field of Indian K-12 education. We conducted an exploratory study to understand the current extent of use of technology in schools, the acceptance of technology by the key stakeholders, i.e., parents, teachers and students and their perception of introducing Augmented Reality technology in classrooms in future. RQ1 focused on finding the acquaintance level of the students with the emerging technologies. We conducted semi-structured interviews to know their outlook toward technology. The results on their attitude toward technology mainly captured how independently they were using the latest gadgets and

Table 63.1 Summarized characteristics of expected AR experience in schools based on the themes generated under the three dimensions of learning

Themes	Instances of user statements	Characteristics of expected AR experience
Dimension of learning: content (*functionality*)		
Conveying information	"Degree of angle rotation can be seen while moving an object," "popping of 3D figures while reading a textbook"	*Visual Cues*: Enabling indication of AR elements in the mediums *Informative*: Prompting related details and information with the 3D graphics *Situational Regeneration*: Explaining the working of past events and situations *Dynamic*: Displaying the interactive motion of contents
Reconstructing objects/situations	"watch Einstein performing experiments in real," "how the earth was made"	
Bringing out the dynamism	"visualizing combining of particles and molecules," "see parallel and meridian lines"	
Dimension of learning: incentive (*sensitivity*)		
Exploring mediums for AR	"see the contents on display board in 3D," "scan globe to see the cultures"	*Developing Interest:* Finding it engaging while the content is explained *Cognitive Sustenance*: Sense of efficiently understanding in one go *Creative Instances:* Feeling of experimenting with innovative mediums *Playfulness:* Feeling of excitement while interacting with elements of AR
3D Depiction of 2D graphics	"country or world map can be visualized for memorizing easily"	
Expressive diagrammatic examples	"while studying gravitational force, one is able to see the occurrence of the event with an example"	
Dimension of learning: interaction (*Integration*)		
Visualizing real-time information	"content taught in class should pop in front of students to help backbenchers"	*Immersive:* Feeling of being engrossed in the interaction of elements and learning *Tangible*: Sense of interactivity with the elements of AR *Familiarity:* Relating with prior knowledge of the associated content *Exploratory:* Sense of experimenting with the AR elements
Linking with familiar day-to-day events	"exploration of teeth in 3D," "watch famous places to visit in 3D"	
Extremities in size	"visualize the constellation right in front of me," "watch microbes in actual"	

applications. Most of the students were dependent on their parents to use their smartphones or any other gadget. Very few students tried to explore materials beyond the textbooks and smartclass modules by using some additional educational applications. However, they mostly used the smartphones of their parents to play games. Many students knew about the popular AR-based game—PokemonGo [19]. However, only four students knew the technology it used, i.e., Augmented Reality (AR), and could describe it a bit.

The teachers were asked about their comfort in using the smartboard technology. The online stored modules helped the teachers to reuse the taught content any time. They believed that it helped students in improving their visualizing skills but yet lacked interaction from students' end. The parents in the study were interviewed after they had experienced the working of an AR display with their children in the mall. After the introductory interview with the three user groups, they were explained about the AR technology and were given the demo using some existing AR-based educational applications. On asking about their perception of introducing AR in classrooms, certain insightful comments were obtained from the three user groups. Most of the participants gave responses by linking the possible features of AR applications with the features of existing technologies. Thus, their expectations were pretty much based on their prior experiences. At times, some of the students went off-topic by being too futuristic with their responses. But they were encouraged to do so in order to get further inferences.

The themes obtained from these user stories were classified under the three dimensions of learning given by Knud Illeris [20]. Based on the themes categorized under the three dimensions of learning, 12 characteristics of expectations were obtained. The suggested characteristics of expectations under "Content" dimension focus on designing the functionality of the AR applications to help the students understand clearly what is taught to them. The suggested characteristics of expectations under "Incentive" dimension focus on designing the AR interactions targeting the emotional intelligence quotient to help the students to bring in the sensitivity of cognition and keep them motivated in the learning process. The suggested characteristics of expectations under "Interaction" dimension focus on designing the AR applications with factors that integrate the functionality of AR interactions with the related incentive.

While designing the AR-based learning applications, designers can use the combination of these characteristic expectations from each of the learning dimensions to help the students in understanding the abstract concepts using features of AR. For example, in order to introduce the different forms of 3D shapes in Geometry to 7th-grade students, the designers can make sure that the interactions using AR provide the "informative" "visual cues" for their "cognitive sustenance" and "developing interest" in "exploring" the 3D shapes. Similar such combinations by using at least one characteristic from each learning dimension from Table 63.1 can be used to evaluate if the AR applications are effectively designed to enhance the learning experiences of the students of different grades in different subjects. This would ultimately help the students to initiate the process of learning with the AR interactions. Thus, in order to provide the students with a satisfactory experience in terms of learning using the AR interactions, these characteristics of expectations must be kept in mind while designing an AR application for schools.

63.6 Conclusion

In this paper, we have focused on understanding the viewpoint of students, teachers and parents with the use of current technologies introduced in Indian schools and the potential introduction of Augmented Reality technology in future. We have thus addressed two research questions. The results of RQ1 focused on understanding the outlook of students in using technology for learning purposes. Students are still dependent on elders to use the accessible technologies. The results of RQ2 focused on arriving at characteristic expectations of AR experience in schools. These characteristics were developed on the basis of the three dimensions of learning given by Knud Illeris [20] to enhance the learning of students using the AR interactions. We posit that while designing an AR application, these characteristic expectations may help in providing satisfactory user and learning experiences to students.

The study has been conducted in a single school. In future work, participants from different demographics having exposure to different types of technologies can be studied to have a better understanding of their expectations and to identify a pattern or commonality among them. This can help in generalizing the characteristics of expectation across the schools in the country. Following this, an AR application built upon these characteristics can be tested to evaluate the validity of the stated characteristics.

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Chapter 64
Study of Icon Design for Indian Market: Preliminary Investigation

Madhura Sekar, Ganesh Sadashiv, Suneira Subramanian, Shreya Venkatesh and Viba Mohan

Abstract Icons on a product effectively communicate the actual functionality of the design. A poorly designed icon which fails to help its users understand about its functions not only affects the usability of the product but also directly reduces its acceptance in the market. More icons representing multi-functionalities of smart refrigerators have resulted in some of them becoming redundant due to lack of understanding by its users. Thus, empathizing with the target user groups in order to understand their needs and wants is a necessity which many existing icon designs fail to do. The study aims to evaluate the level of comprehension about these icons and the need to redesign or discard some of them by analyzing data through comprehension, stereotype, and strength test. Many of the present smart refrigerators carry icon designs, considering mental models of Western nation's users and do not relate entirely to users of India.

64.1 Introduction

Technology has been responsible for creating resources, where all the information we need is right at our fingertips. With the advancement of technology, great discoveries are dramatically changing daily routine. Irrespective of living in a

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bungalow or an apartment, the home is upgraded every passing year. One of the household appliances, by importance, is the refrigerator which preserves foods. Refrigeration appliances have brought an essential transformation in our lives. Integration of smart refrigerators with new technology is popular among the groups for a comfortable and stress-free life. Humans have communicated with visual representations of concepts for thousands of years, but these have been never more relevant than today. When traveling across cultures, imagery and icons are crucial to basic living. Language does not always help that is why we look to icons and images for help and navigation. Icons are so powerful and universal that we can instantly recognize the product and their functionalities. Icons like *emojis* can convey emotions and meaning from one person to another [1]. In the technological world, icons represent a large portion of how users navigate around an appliance such as a refrigerator. Research has shown that icons, when used correctly, can enhance usability, be easily remembered, and improve the design. On the other hand, when misused, icons can confuse and ultimately affect the usability of the product. Icons can also spark a debate regarding their suitability and appropriateness. Well-designed icons combined with text enhance usability and readability and help create a meaningful link between the icons and ideas expressed. The trouble is implementing commonly used pictogram that has contradictory meanings. For example, the 'hamburger' icon is not only used to squeeze additional content into a scrollable overlay, but it is also used to compress the content. The 'Facebook' app uses the icon to squeeze additional, but the 'Big Basket' app uses it as a list of frequently added items. The coloration is too subtle to make users realize that this icon has a different meaning. Other icons that can be frequently misunderstood by users are the 'crushed ice icon' and the 'child lock' present on refrigerators. Many home appliance companies present different designs for these icons which further confuse the user. Many icons are created concerning the cultural background based on that country where the appliance has been designed. Many appliances do not provide icons which can cut across cultural barriers. These icons and their exact meanings are confusing to users. An icon's first job is to guide users to where they need to go. When designed correctly, they communicate the core idea and intent of a product or action. It is a design pattern that is familiar to users. Even with all these benefits, icons can cause usability problems when designers hide functionality behind icons that are hard to recognize. As Curt Arledge [2] says, a single icon can have both solid and hollow characteristics. Icons also help to represent an object, and it uses a real label, which limits the amount of cognitive effort test participants need, to match a name with its icon. An icon's style does not only exist in isolation but should also interact with other attributes like color to create compounding effects on usability. Designing icons should be both semantically clear and visually attractive which is a compound exercise that doesn't lend itself to simple binary rules. For any product to succeed in the market, it becomes imperative that design amalgamates with technology at the micro-level of icons too.

64.2 Literature Review

The use of icons in interfaces is now widespread. It is used to represent objects, statuses, messages, and options. According to Harton [3], user-interface icons are much more than on-screen decorations. Icons play an integral role in enhancing end-user productivity and an application's overall success. They act as a medium of interaction and communication between a user and the application.

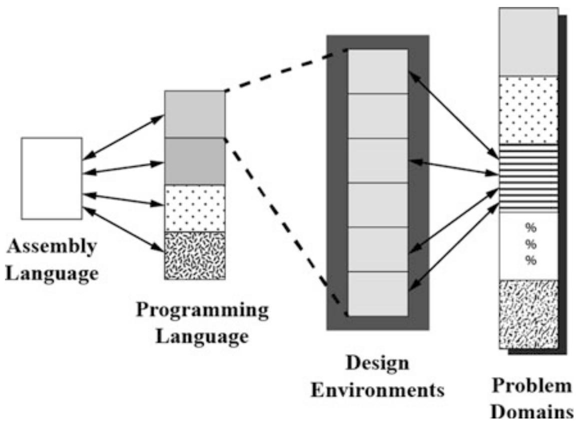
For example, in Fig. 64.1 [4], the most noted problem domains exist between the user and the interface. Thus, if two applications are identical (concerning content, information, navigation, and graphical layout) but are different regarding interface signs, then we can assume that more intuitive interface signs will contribute positively to the usability [5].

Hassenzahl & Tractinsky [6] stated that 'user experience,' a term which previously would have referred exclusively to the usability of an interface, has broadened over the last decade to include our effective response to the interface. Hence, the medium would entail that the user can easily comprehend and navigate complex systems without a hassle. Therefore, icon design plays a vital role in both the user's journey through the app and the holistic user experience.

Several studies have been conducted to assess the essential properties which determine the success of an icon. The most basic definition of a successful icon is one which can be given by its context of use, communicate its intended use to the user. However, according to Jackie and Jordan [4], the user's performance on a new interface may be determined and improved based on three components—guessability, learnability, and experiences user performance.

Figure 64.2 is the typical learning curve as calculated by Moyce [4]. It reflects on the impact of guessability and learnability on a user's understanding and performance concerning any interface. The first stage of design is, therefore, to encode information into a signal which the user can interpret and code [7]. In contrast to other writing systems, visual icons often communicate information in a non-verbal

Fig. 64.1 Visual representation of problem domains [4]



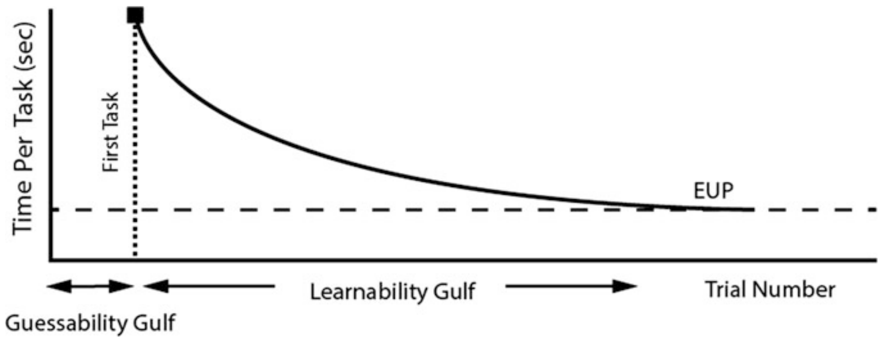


Fig. 64.2 Typical learning curve

manner, not relying on syntactic or phonological rules to convey meaning. They instead rely on a user's ability to decode a sign based on pre-existing knowledge. To do this, we need to take into consideration the user's comprehension of the design based on past experiences, which is known as the user's mental model. Galitz [8] states that as a result of our past experiences and culture, we enrich mental models of the things and people we interact. A mental model is merely an interpretation of a person's current understanding of something. Meaning, when the user interacts with a new interface, he/she will have certain predefined expectations based on the mental models that they have formed. For this reason, it is also essential to design the icon in a consistent manner, which is, 'doing similar things in similar ways [9].' Icons can be consistent in two manners: Rule Compatible and Set Compatible. Rule Compatibility correlates with the existing knowledge of the user and their previous experiences, while Set Compatibility, on the other hand, refers to the consistency of the icon concerning a part or the whole interface [10]. Since Rule Compatibility relieves heavily on the knowledge and past experiences, it often depends on the cultural context of use. It entails that by gaining a clear understanding of the user's background, an icon can be redesigned to be better suited to them in a cultural context.

64.3 Case Study

Samsung established in 1969 at Suwon, South Korea. The company has a massive list of product inventories, for example, LCD/LED TV's, cameras, mobile phones, and refrigerators. Samsung refrigerators were used as a part of research due to its vast acceptance and presence in the worldwide market. Samsung refrigerators use few generic icons; hence, a case study on Samsung refrigerators is carried out in order to understand the various icons used across different models. The number of

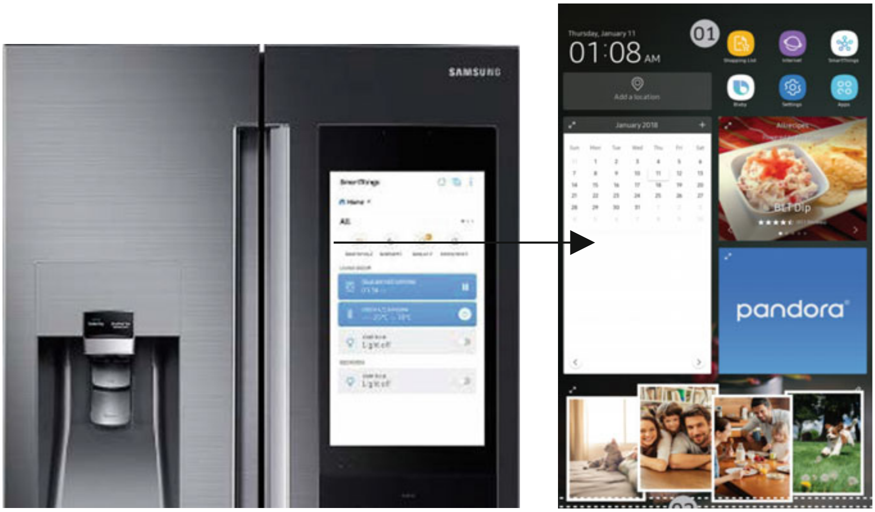


Fig. 64.3 Samsung model no—RF22N9781SG/AA

icons used on the façade of the refrigerator differs with every model. A few of the commonly used icons in Samsung smart refrigerators are shown in Fig. 64.3, Samsung designed these icons concerning the Western market, and thus, these icons are not compatible with the Indian market. The icon for 'crushed ice' dispenser and 'ice off' is the least understood feature (this is proven with the help of our survey). One of the most popular Samsung refrigerators is the Samsung RF22N9781SG/AA.

In Fig. 64.3, the refrigerator consists of a 4-door fridge with a dispenser panel and a digital touch display. The display provides features like music, calendar settings, recipe books, shopping cart, and home settings. The smart setting option consists of important features like brightness, child lock, and power saver options. This provides an easy interface for the users. The dispenser panel does not have any icons on it. Instead, it has two different push in buttons with its features written on it (like water and ice making) in a minimalistic and aesthetic manner. Using their latest voice integration 'Bixby Voice,' they were able to provide the users a hands-free experience as well as making it easier for the visually challenged.

64.4 Gap Analysis

Icons need to be appropriately designed so that they not only enhance the usability of a product but also help the product go global [11]. It is indicated that a cross-cultural study on icon comprehension of users in different countries [12] varies substantially, reaffirming the fact that icons need to be designed for a specific context. The literature review shows most of the work done is concentrated on the usability aspects of icons in isolation and on products. Few cross-cultural studies on icons have been performed, yet the usability of the icons used on products shows that the usability aspects change when the product crosses one geographic boundary to another. In the Indian context, such studies are missing.

Each brand offers different icons and user interface, and even worse, the same brand offers different icons and user interfaces for its devices. These icons are inconsistent and difficult to comprehend or understand without using a user manual. Before the survey, a number of refrigerators were observed, the sample set comprised of refrigerators across different brands as well as different models in the same brand. The common functions among all the refrigerators were taken forward for the study, and inconsistencies in the representation of their icons were noted. This gave an understanding of how current refrigerator brands depict or visualize their functions in the form of icons.

64.5 Methodologies

64.5.1 Overview

A survey was conducted by a team of four students, in the city of Bengaluru in Karnataka. It was to understand how much people know about refrigerator icons. A group of 30 individuals of different age groups was selected as test candidates. The group consisted of a large number of female users (73.33%). All the candidates were well educated and mainly live in Bengaluru. They were aware of smart fridge interfaces, but most of them had not used it. They used the refrigerator on a daily basis.

64.5.2 Components

The first level of the survey consisted of three types of questions. The first type is general questions which are meant to understand the consumer's knowledge regarding the icons used in the refrigerator—the features they generally use, challenges they face, and importance of product demo by the salesman. The questionnaire resulted in identifying the most commonly and widely used icons in a refrigerator and concluded the challenges they face while using the refrigerator. The second type consisted of a set of 11 icons. The candidates were asked to tick the icons based on their memory. Their answers were ranked on a scale of ten (10: very good, 5: average, 0: bad) based on their selections. The third type consisted of 5 ranking questions. The icons were ranked on a three-point scale (10: best, 5: average, 0: bad) by the users.

64.6 Results and Discussions

64.6.1 Physical characteristics

The age of the participants ranged from 15 to 80 years. Figure 64.4 shows the diversity of participants in the survey. The majority of female participants were homemakers whereas the male participants were outgoing. All the participants had an overall knowledge of smart refrigerators and its features. The participants selected for the interview were educated and were living in a metropolitan city in India.

Questionnaire: The icons selected were the familiar icons present in smart refrigerators.

Our participants mostly used the popular refrigerators from companies like Samsung, LG, Hitachi, and Panasonic. A total of 15 icons were mentioned out of which candidates were asked to answer on how many and how well they knew. Table 64.1 tabulates the questions which were used to gather information on how aware the consumers (30 participants) were and how well they could recognize the icons on different types of refrigerators.

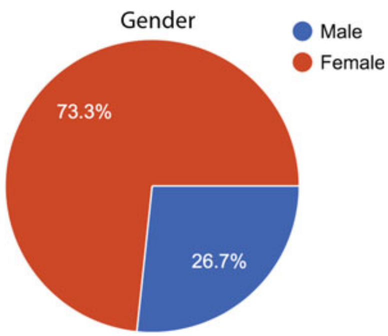


Fig. 64.4 The diversity of participants in the survey

Table 64.1 User feedback on awareness and familiarity

Awareness (smart fridges)	Knows 80% (24 users)	Vague idea 13.3% (4 users)	No idea 6.7% (2 users)
Familiarity with features used (15 icons)	<10 56.6% (17 users)	10 to 15 40% (12 users)	=15 3.4% (1 user)

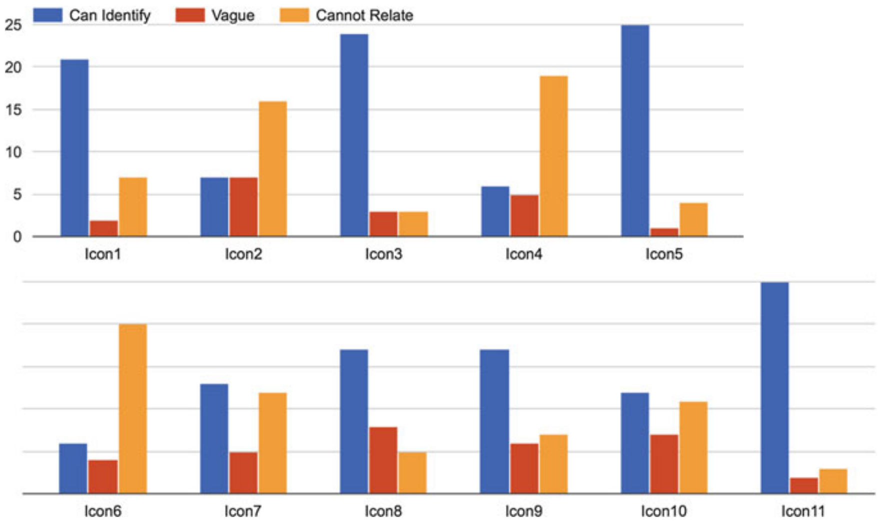


Fig. 64.5 Graphical representation of icons identification by users

Table 64.2 Icons and identification of the same

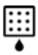
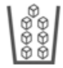
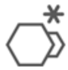
Icon no.	Sign	Color	Meaning	Can identify	Vague idea	Cannot identify
1		Black on white	Energy saver icon	21	2	7
2		Black on white	Freezer/Hold 3 s for power freezer icon.	7	7	16
3		Black on white	Alarm/Hold 3 s for filter reset icon	24	3	3
4		Black on white	Filter indicator	6	5	19
5		Black on white	Lighting icon	25	1	4
6		Black on white	Fridge/Hold 3 s for power cool icon	6	4	20
7		Black on white	Cubed ice icon	13	5	12
8		Black on white	Crushed ice icon	17	8	5
9		Black on white	Water icon	17	6	7
10		Black on white	Ice off icon	12	7	11
11		Black on white	Child lock icon	25	2	3

Table 64.3 Different icons for same functionalities

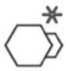
Alarm	Ice-cube dispenser	Child/Panel lock	Crushed ice dispenser	Ice off
				
				
				

Comprehension level: The participants were given a list of existing icons present in various brands to help us analyze how well these icons are understood by the consumer. Through our surveys, we noticed that 24 participants were comfortable comprehending icons with text while the other participants preferred either only icons/glyphs (4 users) or only text (2 users). This also made them more aware of the various existing or new features provided on the smart refrigerators. In Table 64.3, the participants were asked to choose between icons they could identify/had a vague idea/could not identify the icons present. It depicts various icons present in the refrigerator. From the information gathered, 73.3% (22 users) of the participants use less than 4 of the icons present and 26.7% (8 users) used around 4–9 of them. Figure 64.5 shows the same in a graphical form (Table 64.2).

Based on these icons, the participants were asked to rank the icons on a scale of 1–3 (where 1 is very good and 3 the worst). Three icons of the same function were selected from different companies (as shown in Table 64.3). The participants were shown the images of the icons which were used in the different smart refrigerator models. The results of the survey are given in Table 64.4 which gives consolidated result in the form of mean rank, and the ranking is based on best, average, and bad.

Most of the refrigerators in the market are designed for the Western market, keeping their mental model in mind. Thus, making it difficult for the Indian market to understand and use the features (icons), these refrigerators offer. If designers could extract metaphors from Indian culture and heritage and use these analogies to design icons, the usability of the icons will significantly improve.

Table 64.4 Different icons for same functionalities

Icons	Mean Rank	Ranking	Icon	Mean Rank	Ranking
	2.23	Average		1.39	Best
	1.43	Best		2.17	Average
	2.3	Bad		2.46	Bad
	2.1	Average		2.25	Best
	1.6	Best		2.39	Bad
	2.23	Bad		2.25	Average
	2.3	Average		1.33	Best
	2.33	Bad			

64.7 Conclusion

The findings of these surveys play an essential tool for those multinational companies willing to expand their business in diverse countries such as India. Elements of these interface-like icons, which make the product usable, might not work effectively and efficiently in other regions or countries. By analyzing various users' experience and by understanding their preconceived beliefs and catering to them, the icons thus designed will be better suited to the overall user experience and will adhere to the semiotics of that region. Thus, we can conclude by saying the metal model of the target user is the key point to be considered while designing icons.

64.8 Design Direction

Designers tend to focus too much on the aesthetic of the product with a minimal emphasis on the usability of the product. This, in turn, lowers the understanding of the feature by the user. This research points out once again the need for scientific research in design from an ergonomic perspective. When designing a refrigerator, the interface elements like icons are as essential as form, color, and other features of the refrigerators. One thus needs to test the mental model of the target audience or else the design will fall flat. Assuming that a product is accepted by the users in one part of the world does not guarantee that the same would be accepted in the other part. Targeting Indian audience is a huge task as we have diversity in—food, clothing, language, etc. Hence, it is necessary that a rigorous user testing of the product be done on the target audience taking into consideration their regional demographics when the product is in the conceptual stage. This will ensure that necessary changes can be incorporated before the product is released into the market.

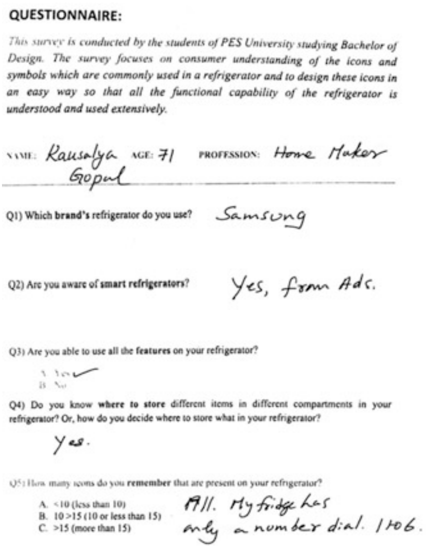
64.9 Scope for Further Work

This work can be extended further to cater to senior citizens, whose overall cognitive process declines as compared to the average population. This group of people is large in number and is using similar electronic products like a cellular phone, smart refrigerators, all of which could be explored, given the fact that as technology advances the refrigerators will develop additional features. The ergonomics of the icon design is emphasized in this research and plays an essential role in the usability and acceptability of the product. The importance of icons lies in the fact that the usability of the device will get reduced if proper icon design is not implemented.

Acknowledgements This research was supported by PES University, Bengaluru, India.

Appendix

A sample from the survey



QUESTIONNAIRE:

This survey is conducted by the students of PES University studying Bachelor of Design. The survey focuses on consumer understanding of the icons and symbols which are commonly used in a refrigerator and to design these icons in an easy way so that all the functional capability of the refrigerator is understood and used extensively.

NAME: Kausalya Gopal AGE: 71 PROFESSION: Home Maker

Q1) Which **brand's** refrigerator do you use? Samsung

Q2) Are you aware of **smart refrigerators**? Yes, from Ads.

Q3) Are you able to use all the **features** on your refrigerator?

A. Yes ✓
B. No

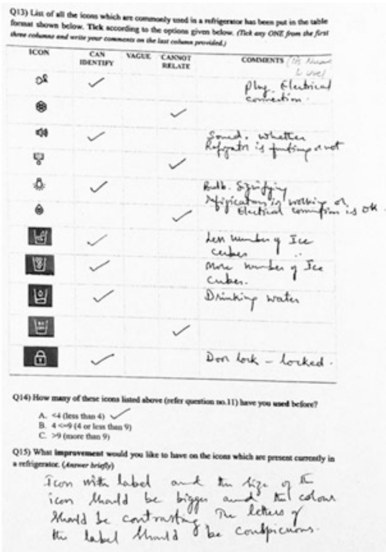
Q4) Do you know **where to store** different items in different compartments in your refrigerator? Or, how do you decide where to store what in your refrigerator?

Yes.

Q5) How many icons do you **remember** that are present on your refrigerator?

A. <10 (less than 10)
B. 10>15 (10 or less than 15)
C. >15 (more than 15)

All. My fridge has only a number dial. 1106.



Q13) List of all the icons which are commonly used in a refrigerator has been put in the table format shown below. **Tick** according to the options given below. *(Tick any ONE from the first three columns and write your comments on the last column provided.)*

ICON	CAN IDENTIFY	VAGUE	CANNOT RELATE	COMMENTS
	✓			Plug. Electrical connection.
			✓	
	✓			Sound. whether Refrigerator is functioning or not
			✓	
	✓			Bulb. Signifying refrigeration is working or
			✓	Electrical connection is ok.
	✓			Less number of Ice cubes
	✓			More number of Ice Cubes.
	✓			Drinking water
			✓	
	✓			Door lock – locked.

Q14) How many of these icons listed above (refer question no.11) have you **used** before?

A. <4 (less than 4) ✓
B. 4<=9 (4 or less than 9)
C. >9 (more than 9)

Q15) What **improvement** would you like to have on the icons which are present currently in a refrigerator. *(Answer briefly)*

Icon with label and the size of the icon should be bigger and the colour should be contrasting. The letters of the label should be conspicuous.

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Chapter 65
Exploring Need in Narratives: Human–Computer Interaction in the Design of a Home Automation System for the Elderly People

Himanshu Panday, Vaishnavi Deepak Bhope and Bishakh Bhattacharya

Abstract The research paper aims to examine possibilities of establishing a framework for generating insights pertaining to requirements from narratives of users, contradictory to the prevalent establishment of initiating from a need statement. The study shapes open-ended discussions of phenomenological probes as a research tool to structure a negotiated understanding of requisites. The elderly and their participatory engagement with the surroundings were established as a research space for the study, and their narratives were sequentially converted into partially analyzed data, initial and focused codes to comprehend understandings in emerging themes. The concluded themes and their categories illustrated a need of exploration in interaction platforms available to elderly. Emerged themes also facilitated in understanding the shortcomings of contemporary techniques of human–computer interaction. Design of a home automation system is proposed as an example to implement the suggested framework in the context of human-centered design. Validation of the framework for a wider spectrum of design transactions is a subject of future study.

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65.1 Introduction

Design activities can be considered as a negotiated phenomenon understanding between design space, design process and the designer him/herself. Products of design expeditions demonstrate a dynamic relationship of the design problem with the contextual constitutes. In contemporary practices, rigorous attempts are made to render the problem statements into actionable goals. However, the praxis does not emphasis at the very emergence of the problem statement. Such endeavors may often lead to consideration of inferior priorities or misconstruction of reality in the concerned space. The research study is among some of the initial attempts to devise a framework for shaping the requisites from within the stakeholders utilizing phenomenology to reach a negotiated understanding of their essentials.

65.1.1 Methodological Void

In *The Reflective practitioner* [1], Schön argues about the uniqueness of the design expeditions and the interdependence of design problems and design processes. The novel existence of deign transactions is largely shaped by its context, and it is an essential parameter to understand the design activity. In contrast, a rational model of design process [2] can be largely seen as discrete sequential process which questions its ability in effective articulation of design space. A procedural investigation situated within objective observations might be helpful in reiterating the scope of necessities or evaluating related hypothetical assumptions. However, a paradigmatic standpoint in constructivism provides a firm ground in exploring stakeholder's experiences and situating their narratives with surroundings to create meaningful products. Established human-centered design methods such as contextual inquiry [3] present opportunities to integrate epistemological stance in portraying context into conceptual upbringings [4]. Nevertheless, such approaches more often serve as an investigational approach for directional motives, and the collected data are used to form and cross-validate hypotheses for preordained purposes. In contrast, ethnography as a qualitative research tool demonstrates the potential to determine the reality of concerned design space. However, designer's need of introducing artifact is opposed to the fundamental bias of ethnography against intervention [5]. Further, a responsible conclusion of an ethnographic study and its coherent inclusion in artifacts is subjective to designer's skills [6]. Contemporary approaches in qualitative design research methods lack a framework to construct grounds for design intervention while bracketing preordained motives. Thus, the void of methodological improvement provides opportunity for phenomenology to assist design researchers in formulating effectual insights about legitimate concerns in the design space.

65.1.2 Phenomenology and Design

Creswell defines phenomenology as the meaning of lived experiences of a phenomenon for several individuals [7]. Phenomenological methods like interpretative phenomenological analysis transform individual narratives to an object of global human experience [8]. Raw information of research participants' interpretations of their surrounding has the ability to represent their concerns by their lenses of reality. In parallel, design as a discipline creates artifacts which assist and shape experiences of users. Recent methodological advancements in design research have used phenomenology to understand the philosophical meaning of introduced design intervention [9]. However, the amalgamation of both practices has been prioritized only in the evaluation of conceptual upbringings and reshaping the need statement [10, 11]. The potential of phenomenology in understanding, analyzing and articulating the priority requisites of design participants is under-researched. In this study, we suggest a framework to adapt phenomenological probes within conventional product design cycle to develop meaningful artifacts for concerned design space.

65.2 Proposed Amalgamation Model

We introduce a hierarchical consolidation model of the antecedent deployment of phenomenological probe followed by traditional problem-solution approach of human-centered design cycle (Fig. 65.1). The method has been framed considering affluent transitions between observation, action and reflection phases. Distinctive procedural identities in the proposed methodology allow a designer to transit between generative and evaluative frameworks of design.

65.2.1 Phenomenological Probe

Concerned Design Space: Locating the design space is a subjective choice of designer's own instincts. However, the decision should be supported by deep concerns of researcher's practices for the context and its stakeholders. Considering constitutes and participants as a whole, a reflexive narrative of rationale is essential for the researcher to locate and discretize his/her motivations.

Structuring Elements

Locating the researcher: In phenomenological research, the ability to identify and suspend the biases of own is essential to protect authenticity of collected data. Self-assessment of contextual pre-assumptions and collaboration with other researchers is helpful in shaping the conscious partiality [12] of researcher's identity and in increasing reliability of phenomenological enquiry. Designer's

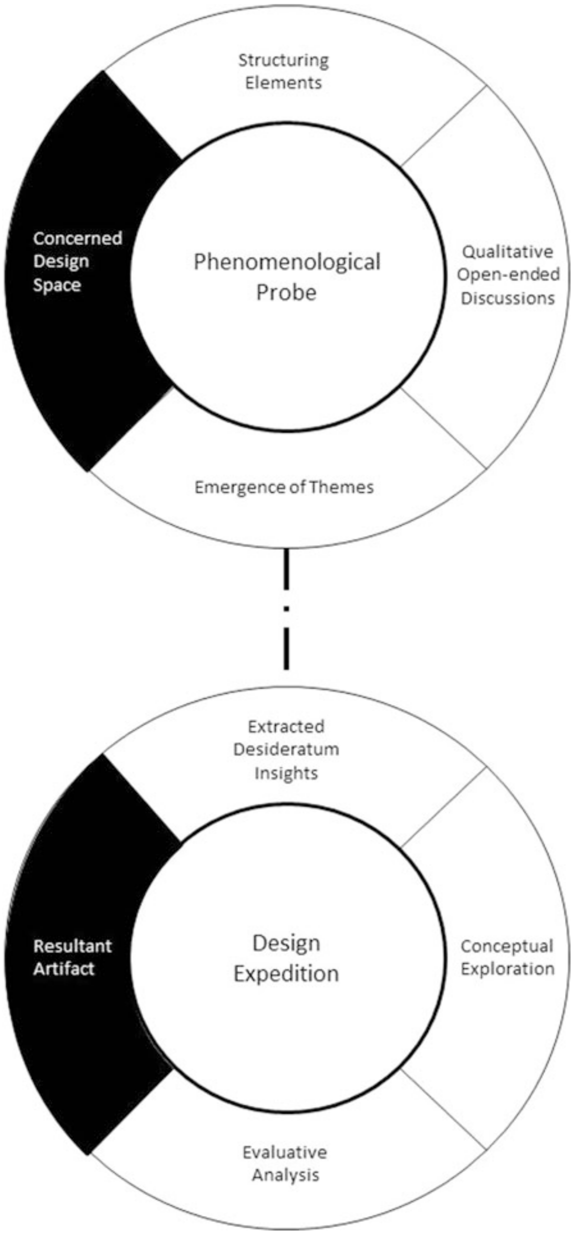

Fig. 65.1 Proposed amalgamation framework

paradigmatic standpoint and motivations are also necessary to be articulated in situating oneself in the design space.

Sampling: Criterion-based sampling is proposed for selecting research participants [7]. The selected research participants should have adequate experience of the contextual design space, and they should be able to effectively express their experiences to the researchers.

Qualitative Open-Ended Discussions

A qualitative styled long unstructured interview is suggested to explore the experiences of the participants. Initial probes in the shape of targeted question can be used to initiate the discussion. Researcher should use prompt inquiries to focus on the themes which might emerge during the interview. Suitable venues and room settings are significant considerations for uninterrupted and comfortable event for the participants. Repetition of the procedure is necessary until saturation of the collected data.

Emergence of Themes

Logical deduction of the collected data is achieved by sequential coding of research participants' narratives. Six phases of thematic analysis [13] are suggested for generating and categorizing themes in a systematic manner. Emerged themes are reevaluated against transcripts of the narratives. A comprehensive draft of themes supported by excerpts of the narratives should be the conclusive procedural product of the process.

65.2.2 Design Expedition

Extracting Insights

Emerged themes from phenomenological endeavors should serve as means of identifying the key challenges with concerned design space. A cross-linking within the themes is established to frame the actionable goal for the design expedition. However, a reflexive evaluation with collected data is necessary to minimize misinterpretations. An iterative approach to convert a broad problem statement to discrete parameters can also be implemented by referring to the excerpts of research participants' narratives. The procedural conclusions are expected to serve as both design constraints and functional requirements to guide through conceptual rendering and evaluative analysis.

Conceptual Exploration

Actionable design insights in social context are usually contradictory and intertwined. A mixed method approach using axiomatic design and TRIZ [14] is suggested to exploit discretization capabilities of axioms and innovation potential of TRIZ matrix in contradictory goals. However, the choice of methodological medium for conceptualization depends on paradigmatic standpoint of the designer. An alternative technique such as adaptable design or brainstorming can also be preferred based on designer's experience and expertise in the method [15]. A mapping of design solutions with parametric constraints should reflect the emerged themes of phenomenological enquiry.

Evaluative Analysis

An evaluative framework is constituted by employing two-phase validation. In first phase, a weighted design matrix [16] can be used for global parametric comparison with contemporary solutions and the outcome can be considered for iteration if any. Thereafter, the design product is evaluated with the research participants to integrate their feedback in the artifact.

65.3 Case Study

We implemented the suggested methodology in the context of elderly and their surroundings. The framework assisted the design team in understanding research participants' concerns, shaping the requisites and designing for provided functional requirements and constraints. The procedural experience and the evaluation results are encouraging.

65.3.1 Qualitative Research

The elderly and their surroundings were chosen as a design space because of the emerging necessities of taking care of a significantly large elderly population in the country [17]. The reasons to devise a course of action were motivated for shaping comfortable arrangements for elderly's life. A social constructivist paradigm was chosen as a standpoint because of its relevance to the research interests. Our own assumptions regarding research participants and their capabilities were summarized to bracket our pre-assumptions. Further, we were aware of the biases which might be introduced by social perspective of age. Six participants between the ages of 60–70 were selected for the study. An unstructured long-interview method was used to explore research participants' experiences. We were confident that categorical saturation will be attained after analysis of the narratives. Hence, no further sampling was pursued. Sequential coding using initial and focus codes was performed on the transcribed narratives. An interpretive analysis was performed on emerged focus codes to render appropriate themes in accordance with the proposed methodological skeleton (Fig. 65.1).

Emerged Themes

Reliance: Feeling of dependence was common among the participants. The theme is evidenced in the narratives as follow—"..sometimes, I feel so helpless as I have to ask someone to do all these small things for me.. I am not encouraged to walk due to my joint pain" The following narrative further exemplifies the theme —"I am on the mercy of my grandchildren. They choose how I live.."

Financial Constraints: Another prevalent theme was the economic conditions of the research participants. Some of the participants illustrated how they are being denied the comforts of life due to their inability to afford highly priced objects. "..for all these times, I am not able to provide precious gifts to my grandchildren. My pension does not account for much. Their visits are infrequent now. Sometimes I wish they were here to help our survival…"

Limited Accessibility: Accessibility issues were very prominent among the research participants. The hindrances covered a wide spectrum of actions such as reading books and signs, cognitive load in interaction with digital interfaces and physical accessibility issues caused by mobility restrictions. Multiple narratives of the participants supported the theme. However, all of them indicated comfort with the mediums which had emerged during an early stage of their life (basic phone and television). The interpretive argument is established by the following and similar narratives—"we were watching the TV when I got her (daughter) call… when they (children) gifted the phone, we tried our best to learn but we are not capable of operating these touch phones. Our *nokia* is the best choice for us…. He never picks up my call. I'll hang up after two rings and he will call me back."

65.3.2 Design Expedition

Emerged themes shaped our actionable problem statement which was persuaded for design solutions. Multiple brainstorming sessions were conducted to draw insights from the themes and to validate them with the transcribed narratives. After multiple iterations, an interpretive problem statement focusing on exploration in parametric control of surroundings of the elderly emerged which was well supported by the collected qualitative data. The themes provided us the design considerations to utilize existing interaction capabilities to control the suggested system. A mixed method approach [14] was used to generate several design solutions. Further, a local and global comparison on parameters of interests was achieved by simulations on weighted design matrix. Conclusive prototype is a home automation system which consists of a dialer-based trigger, a controller unit built from electronic waste of junk mobile phone and a relay unit to control high power appliances. Designed interaction channel has an auditory responsive playback unit which is triggered by numeric keypad of user's existing phone. The proposed system is being tested with the research participants, and some of their feedback has already been included in the current prototype. Figure 65.2 illustrates some highlights of the design process. The introductory experiments have shown a smooth adaptability of the elderly with the unit. Their feedback on the interaction medium is decidedly

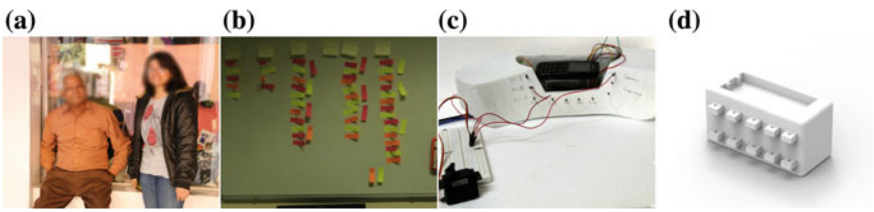

Fig. 65.2 Snapshots of the design process **a** selecting research participants, **b** arranging narrative in themes, **c** technical simulation of selected concept and **d** 3D model of product shell

positive, and we are looking forward to an evaluative quantitative study of the proposed solution with a wider set of elderly participants.

65.4 Conclusion and Future Scope

The proposed methodological amalgamation of phenomenology and conventional human-centered design process provided an effective framework to integrate the rational and the reflective paradigms of design expeditions. The key contribution of the research paper lies in emphasizing and suggesting a procedural framework for the emergence of the need statement through symbolic-interactionist perspective. Phenomenology as a qualitative research tool has been established to shape and reiterate the problem statement and has shown promising results as an evaluative measure of procedural improvements in the design cycle. An investigational attempt has been pursued with elderly and their surroundings. A design expedition has also been carried out to demonstrate and validate transitions of theoretical establishments to tangible scenarios. Validation of the framework for a wider spectrum of design transactions is a subject of future studies.

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Chapter 66
Exploring 3D Interactions for Number Entry and Menu Selection in Virtual Reality Environment

Akriti Kaur, Ashutosh Agrawal and Pradeep Yammiyavar

Abstract Graphical user interfaces (GUI) on mobiles involve user interaction of touch input on a two-dimensional surface. With advances in virtual reality (VR), possibilities of three-dimensional 3D GUIs will emerge. Current study on designing interfaces for VR deals with incorporating rules of 2D GUIs. The question here is that whether such an approach is optimal for a VR environment? Designing interactions and interfaces for VR deals with issues that are different from flat 2D screens like field of view, orientation of the user, having no defined reference plane and depth-related issues. In order to solve such ambiguities in the design of VR interfaces, an experiment was conducted with 30 users comparing three different keypad interfaces in the virtual world via head-gaze interaction. Subsequently, inferences drawn from this study were used to design and prototype two more interfaces where hand gesture (HG) and natural object interaction (NOI) based techniques were explored using a single layout of dial pads and menu items. A research experiment comparing the two interaction techniques for an online money transaction scenario was designed and conducted with 20 different users. The paper discusses different interaction techniques and compares 2D dial pad interface with a 3D interface. The paper also discusses insights on the task performance, the usability of such interfaces and cognitive workload while using them.

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66.1 Introduction

Virtual environments help users overcome position and time constraints to access information, and it extends visual information to the third dimension, hence making spatial interactions more productive compared to two-dimensional interfaces [1]. With applications in varied fields like entertainment, education, and medicine, an immersive experience with innovative interaction techniques can be provided through VR [2]. However, recent work in designing VR GUIs attempts to apply 2D techniques to 3D worlds, adopting interfaces from 2D GUIs [3]. Reason for such adoption can be the challenges faced in designing VR interfaces, like distinctive visual and interaction characteristics compared to 2D interface design [4]. Real world experiences are intuitively connected with our interaction in the 3D virtual world; hence, these can provide means for immersive UIs and more holistic interaction design [5]. While designing complex interfaces in VR, questions related to placement of elements in space, depicting their motion, user interaction with each element and hierarchy of this interaction are faced. In order to get a direction for designing such interfaces, spatial mobile keypad arrangements were tested in VR environments. Results drawn from this study were used to design an online money transaction interface in order to explore hand gesture and natural object interaction techniques in VR involving menu selection and number entry. Numerous studies were referred to design a usable interface for this scenario. RapMenu design proposed for menu selection on distant displays uses roll and pinch method to select an item [6]. A comparative study of linear, marking and finger-count menus show that the finger-count menu poses a greater mental demand [7]. However, another work on finger-based 3D gesture menu selection found that finger-count menus are significantly faster than other gesture-based selection techniques and 3D marking menus [8]. TULIP menu is a novel interaction technique for system control tasks in VR where each finger is allotted with a menu item and a pinch gesture is used to make a selection [9]. Circular arrangement of menus proposed via ring menus uses a tracking device for the user's hand. Item selection task is performed by rotating the hand and placing the item into a selection bucket [10]. Another technique proposed for multi-level radial menus using 3D hand gestures uses different combination of fingers to create hand gestures for selection and navigation. Although radial menus are ideal for small data sets, larger menu items are usually displayed via traditional layouts [11]. An experiment by Das [12] builds a comparison via different layouts, placement and pointing methods, explaining results through depth (menu levels) and breadth (number of menu items). A study done by Mine [13] explores body-centered menus, i.e., relative to the body which reduces the issue of depth perception in VR as the user can make decisions relative to his own body.

66.2 Prototypes

Design of the interfaces addresses important concerns of VR interface design: (1) layout of elements in VR, (2) user preference of interaction techniques in VR and (3) user orientation and depth-related issues in VR.

Design of Spatial Mobile Keypads in VR: The three VR prototypes of spatial mobile keypad were developed for Google cardboard using Unity3D and Vuforia SDK. The 3D model was designed in Google Sketchup. The interfaces that were developed are shown in Fig. 66.1. The first interface, the 2D keypad (refer Fig. 66.1a), uses flat 2D keys similar to conventional mobile keypad. Pointing the gaze pointer on a number key highlights it and displays the number on the top panel. Upon completion of task, a green call button had to be gaze pointed on. Since the first interface was very static in nature, rest two interfaces were designed to address an additional question—how do we show motion in VR interfaces?

The second interface, the cubical keypad, uses 3D cubes as keys for dialing a number (refer Fig. 66.1b). These cubes were double line arranged in order to minimize head movement of the user and to keep all elements of the interface in a single field of view. Pointing a key (cube) using gaze pointer animates it to fall down (it was a design decision to make the animation falling down to seem natural) to reach a position forming a straight line with subsequently pressed keys, all arranged in front view (dialed panel). Once this animation is complete, the number key (cube) reappears in its position to incorporate repeated entry. A call button is present in line with the above arrangement, pointing at which indicates completion

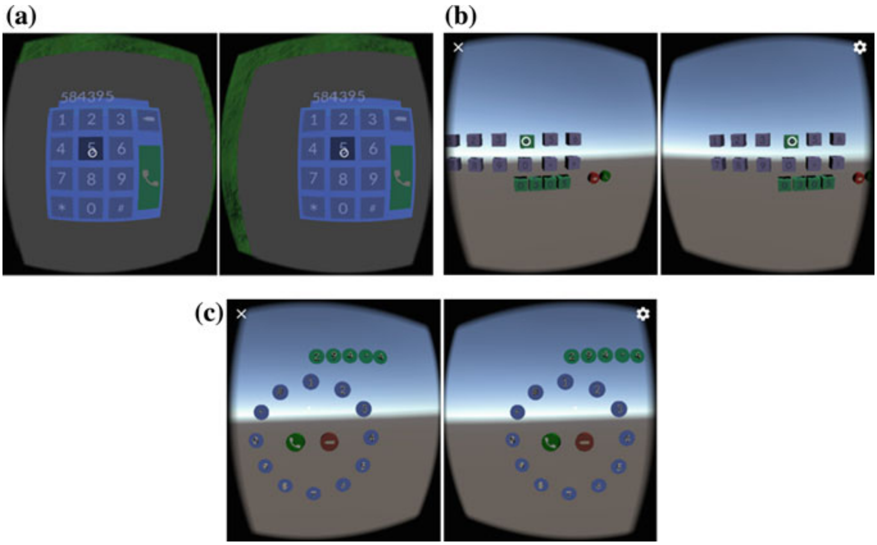

Fig. 66.1 From left to right—**a** 2D VR keypad interface, **b** cubical VR keypad interface and **c** circular VR keypad interface

of number dialing task. The third interface, the circular keypad, uses spheres as keys for dialing a number (refer Fig. 66.1c). A design decision was made to make the arrangement circular in order to reduce the error of gaze pointing to an undesirable number key in the process of passing over it to reach the desired key, which is very much possible in matrix-like arrangement. In this interface, pointing a key (sphere) animates it to reach a top panel similar to a mobile keypad where the dialed number appears on the top. Once this animation is complete, the number key (sphere) reappears in its position to incorporate repeated entry.

Design of VR prototypes for online money transaction: The two VR prototypes for online money transaction were developed for HTC Vive (mounted with Leap Motion controller) using Unity3D and Leap Motion SDK. The online money transaction in VR consists of three steps, viz. (1) selection of mode of payment (refer Fig. 66.2a, b), (2) selection of a credit card (refer Fig. 66.2c, d) and (3) 4-digit PIN entry (refer Fig. 66.3). The layout of menus and dial pads is similar across the two prototypes. Menu selections are performed using HG in one prototype and NOI in the other prototype. A design decision was taken that the textual menus be body-referenced and menu items with visual elements/icons/images be world-referenced. This will improve selection accuracy and visibility and reduce cognitive load (Table 66.1).

Other gestures include a thumbs-up gesture of the right hand used to confirm a selection (refer Fig. 66.3d) whereas a cancelation is exhibited using the index fingers of both hands joined in the form of a cross (refer Fig. 66.3c).

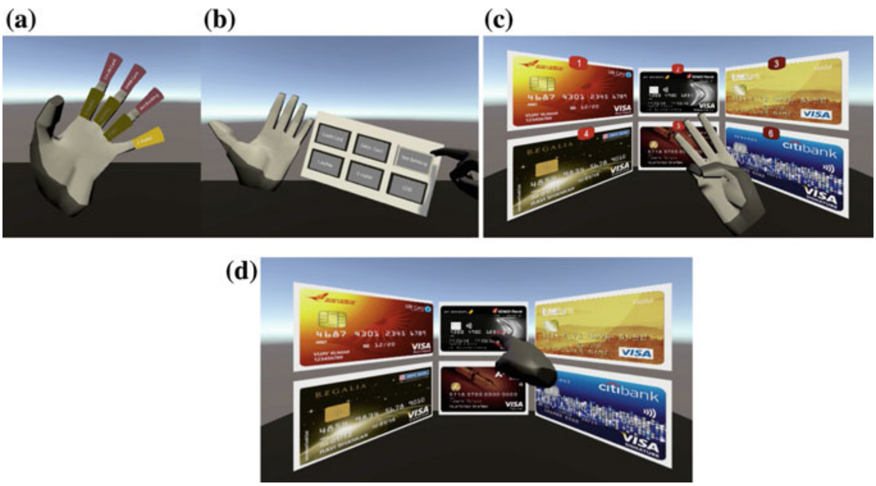

Fig. 66.2 From left to right—**a** body-referenced menu in HG interface, **b** body-referenced menu in NOI interface, **c** world-referenced menu in HG interface and **d** world-referenced menu in NOI interface

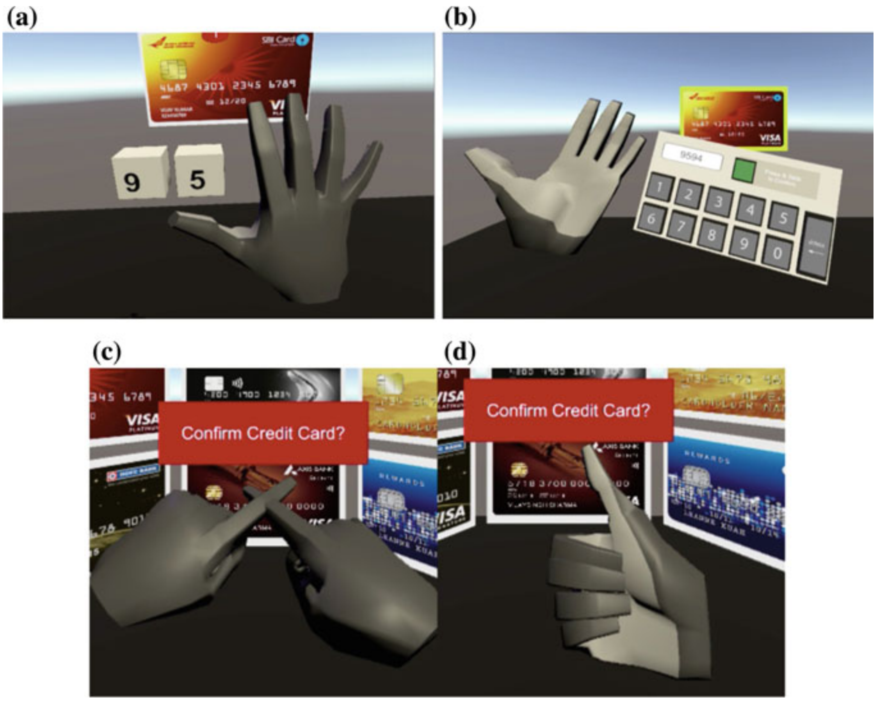

Fig. 66.3 From left to right—**a** number entry using finger counting in HG interface, **b** number entry using body-referenced menu in NOI interface, **c** cancelation gesture in HG interface and **d** confirmation gesture in HG interface

66.3 User Study

User studies were conducted as part of two experiments:

Experiment-1
An independent group study was conducted among 30 participant users of age group 18–22 years. The users were familiar with mobile phone dialing system and were proficient in interacting with smartphones.

Experiment design: Independent variables include (1) three VR interfaces of spatial mobile keypad and (2) past experience of participants in VR. Dependent variables include (1) time, (2) workload and (3) perceived ease of use and usefulness.

Experiment process: The participants were briefed about the functioning of the prototypes at the beginning of the experiment. Scenarios describing use cases of the application of our prototypes and gaze pointer method of input was explained. These included explaining future reference of our proposed design, for example, how dialing systems in VR could be useful for dialing a number in the middle of a VR game. What interface would you probably use in such a scenario? The experiment was conducted

Table 66.1 Comparison of different interaction techniques used

Steps in money transaction	Hand gesture-based interface	Natural object interaction-based interface
Selection of mode of payment—consists of six textual items that are body-referenced (Fig. 66.2a, b)	Menu items appear as labels on fingers of the left hand only when it faces the headset. Selection is done using pinch gesture, (inferred from TULIP menu [9]) followed by feedback sound. The index, middle and ring fingers consist of two labels—(1) active label nearer to fingertips and (2) inactive label nearer to the palm. Switching between the active and inactive labels is achieved by selecting 'more' label on the pinky finger	Menu items appear on a panel consisting of two rows of three items each. Selection is done by 'pressing and releasing' the menu item via index finger of other hand. Each successful click is accompanied by a relevant feedback sound and change in color of the button
Selection of credit card—consists of six different credit cards that are world-referenced. These cards appear as digitized versions of the original cards in a curved rectangular arrangement as shown in Fig. 66.2c, d (inferred from Muffin 3D marking menu [17]).	Cards are labeled 1-6, and a card is selected via finger-counting gesture, followed by feedback sound	The relevant card is selected by 'pressing and releasing' it against a reference plane using the index finger of either hand, accompanied by a feedback sound and change in color of the reference plane
Entering 4-digit PIN of selected card to make payment (Fig. 66.2a, b)	The selected card is displayed and PIN is entered using finger counting	The selected card is displayed. A panel consisting of two rows appearing as the left-palm faces the headset

in three groups of ten participants each. Each group was tested with one VR keypad interface out of the three. Each participant was initially asked to dial a phone number in a conventional mobile keypad (this was done so that all users have the same reference), following a task of dialing a ten-digit mobile phone number in the VR keypad interface allotted to him/her, in a single trial. The same phone number was given to all participants during their respective task. After completion of the task, NASA-TLX workload assessment sheet was administered [14]. Post this, a questionnaire of perceived ease of use and perceived usefulness [15] was rated on a Likert scale of 1–5 (1 = strongly disagree, 5 = strongly agree). Semi-structured interviews were also taken from the users.

Experiment-2

A within-group study with 20 users of age group 18–22 years was conducted for the second experiment to compare the two interactions. None of the users had prior experience with any VR application. However, they all were proficient in making online transaction using smartphones and desktops. The experiment duration ranged from 40 to 50 min.

Experiment design: Independent variables include (1) two VR interfaces for online money transaction and (2) past experience of participants in VR. Dependent variables include (1) task completion time, (2) workload and (3) system usability.

Experiment process: The participants performed the experiment seated on a chair. They were first given a demographics questionnaire. The participants were briefed about the functioning of the prototypes at the beginning of the experiment. They were given a training module for a particular interface to practice as long as it took them. They were explained the scenario of how the proposed system can be used in future for any online purchase in VR. A scenario of online shopping in VR and then proceeding to online payment was described. The users were then asked to perform a task using the given interface (both interfaces given one after the other). The task is to complete an online money transaction in VR using the three steps mentioned above, i.e., selection of mode of payment, selection of credit card and entering 4-digit PIN. All users were given the same 4-digit PIN combination. To counterbalance the learning effects, the order of interfaces was randomized. Immediately, after completion of task on an interface, NASA-TLX workload assessment sheet was administered. Post this, a questionnaire of system usability scale (SUS) [16] was rated on a Likert scale of 1–5 (1 = strongly disagree, 5 = strongly agree) to test for usability. Semi-structured interviews were also conducted.

66.4 Findings

Findings from Experiment 1

Time: The time taken to complete the task of dialing a ten-digit phone number in the initial VR interfaces was calculated from screen recordings. The data was found normally distributed. Independent sample t-tests showed that the meantime taken for task performance in circular keypad interface is significantly more than the time taken in the other two VR interfaces ($p < 0.05$). Although a significant difference in meantime taken for task performance in cubes keypad interface and 2D keypad interface is not found, the effect size is found to be $d = 0.653$. Hence, due to lesser number of participants and moderate effect size, we can conclude that the meantime taken in cubes keypad interface is more than that in 2D keypad interface. This might be due to an initial learning curve involved in the cubes keypad interface, as the users are not used to such an arrangement of number keys.

Workload: The calculation was done as per followed by NASA-TLX, and mean WWL score of each participant was calculated. The data was found normally distributed. Following t-tests shows that workload comparison between circular and cubes keypad interface has a $p = 0.105$ and $p = 0.109$, respectively. Since this is a two-tailed value, single tailed result and a large effect size $d = 0.8055$ show that workload of circular keypad interface is significantly more than that of cubes keypad interface. Comparison of the workload of circular keypad interface with the 2D keypad interface shows an effect size $d = 0.705$. Although there is no significant difference in the overall mean WWL score of both the interfaces considering $p > 0.05$, since the effect size is moderate, we can conclude that workload of circular keypad interface is significantly more than that of 2D keypad interface, considering the less number of participants. Hence, circular keypad interface has significantly more workload compared to the other two interfaces. This can be because of increased head movement due to the circular arrangement of number keys.

Perceived ease of use and usefulness: Each participant filled a questionnaire based on SUS and TAM model. Semi-structured interviews were conducted to get user feedback on the interface and understand user satisfaction level. The mean of perceived usefulness of 2D keypad is maximum since users find it useful to use an interface similar to conventional mobile keypads. There is less learning involved in this case. Some users also stated that there are chances of error in the 2D and cubes keypad interface when shifting from one number key to the other since the gaze passes through other number keys in the path. The mean of perceived ease of use of the circular keypad interface is more than the other two keypad interfaces. Some users stated that circular arrangement reduced error as they had enough space to move from one number key to the other. However, some felt circular arrangement increased their head movement during the task.

Findings from Experiment-2

Time: The time taken to complete the online money transaction task was calculated from screen recordings. Due to some technical difficulties, time for $N = 3$ participants could not be calculated though the participants had completed the task successfully. The data for $N = 17$ participants was found normally distributed. Paired sample t-tests showed that the mean time taken for task performance in the two prototypes with different interaction techniques is not significant ($p = 0.199$, $p > 0.05$). Meantime for HG-based interface was found to be 50.35 s while that of NOI-based interface was found to be 58.18 s.

Workload: Mean WWL score was calculated for $N = 20$ participants. The data was found normally distributed. Following paired t-tests shows that there is no significant difference in the mean WWL scores of the two interfaces ($p = 0.611$, $p > 0.05$). The mean WWL for HG-based interface was found to be 7.99 while that of NOI-based interface was found to be 7.68. As both the interaction techniques were novel for the user, under similar experimental setup, the workload experienced in both the interaction techniques came out to be nearly equal.

System Usability: The data was normally distributed. The mean usability score for HG-based interface was found to be 59.38 while that of NOI-based interface was found to be 64.00. On performing the paired t-test, no significant difference was found between the means ($p = 0.556, p > 0.05$). Thus, no significant difference was found between the two interfaces in terms of time, workload and overall usability. This was also reflected in the users' preference among the two interfaces where $N = 11$ users (55%) preferred HG-based interface while $N = 9$ (45%) preferred NOI-based interface.

66.5 Discussion

In this paper, three input interaction techniques for VR environments, namely head-gaze, HG and natural object interaction were explored. It was found that in scenarios where user's hands are engaged while interacting in virtual environments, gaze pointing can be highly helpful. However, users should be allowed to control the duration of the functionality of the gaze pointer as per convenience. It was also found from the initial study that the users find menu arrangements similar to that in GUIs more intuitive and easier to use.

The second experiment indicates that the choice of interaction technique does not affect users' performance, workload and usability of the interface for online money transaction scenario. Though most users found NOI-based interface to be more intuitive as it resembles the touch interaction in smartphones, yet 55% users preferred HG-based interface due to its novelty, lack of depth-related issues and faster task completion time. Despite higher preference of HG-based interface, users felt that finger-counting gestures involved lot of thinking and fumbling of the fingers. Almost all users found the cancelation gesture frustrating as they found it cumbersome to assume that hand posture. This might have also occurred due to poor visual feedback of hands in the virtual world owing to technical constraints of the Leap Motion controller. Pinch gesture was the one most appreciated by the users due to faster learning curve and simplicity of the gesture. Users also preferred to always use only one hand to interact with the system and found it tiring and confusing to use both hands. However, some users found it easier to select menu items on body-referenced menus which required the use of both hands as they could use their left hand as a reference plane to estimate the depth of elements. Future work might involve designing hand gestures which are culturally relevant for various interaction tasks in VR.

66.6 Conclusion

The paper reports two experiments designed to understand the interface and interaction technique best suitable for VR environments. In order to answer the question whether using 2D GUIs for designing VR interfaces is an optimal choice, the first experiment claims that users feel more comfortable using the 2D-based keypad interface. If we take a basic scenario of dialing a phone number, we observe that 2D GUI is something people have used since long and hence is more effective. Since most of our users are new to the VR environment, using a 2D GUI initially would make their job easier. Once they adapt to the VR environment, we could slowly shift them to using 3D GUI-based systems. Taking this into account, we designed our second experiment to test two different interaction techniques laying rules of 2D GUI for the menu interface. We used hand gesture-based interaction in the first experiment and natural object-based interaction in the second. We understand from the second experiment that using different interaction techniques had no significant difference on the user. An important design decision taken to build the second experiment was that all textual menus be body-referenced and menus containing visual elements be world-referenced. This made it easy for the users to access menus and helped solve the problem of depth perception in VR.

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Chapter 67
Universal Design Principles in Graphical User Interface: Understanding Visual Ergonomics for the Left-Handed Users in the Right-Handed World

Abhinav Basak and Shatarupa T. Roy

Abstract The advent of graphical user interface in computers has helped users to easily access its features, thereby become familiar with the computer environment quickly and enhance the overall performance of the system. As the GUI evolved, the accessibility options of the user interfaces were expanded to cater benchmark users or extreme users. However, whether the accessibility options provided by operating system manufacturers are discoverable or readily available to the users is a questionable affair. One solution to this problem could be designing the interface in such a manner which could be universally acceptable and usable by all user categories. Although this option seems practically impossible since different user categories may have different needs, the user base of the particular GUI could be maximized. This paper intends to study the accessibility options provided in a computer interface by critically analyzing the problem faced/likely to occur to the users with the objective to come up with design solutions to expand the user base of the existing operating system.

67.1 Introduction

There is always a discussion on the usability issues faced by the left-handed population, whether it is the tangible or intangible interaction. Left-handers always have to deal with the products available around them which are usually designed for the right-handed world. Left-handers are never generally considered as the part of the human population, and very few products are custom designed for them

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considering their requirements. These products could be rarely discovered, be it scissors, can openers, school desks and what not. Unable to find the customized left-handed products, the majority of the lefties forcefully get adapted to using the things readily available to them which are meant for right-handers only. This, in turn, restricts the efficiency of the task performed by a left-hander. For example, when a left-hander operates a pair of scissors designed for right-handers, they either cut an object upside down or start using it with his/her right hand.

Similar is the experience with the digital mode of interaction. We use a lot of digital devices in our day-to-day life which includes PCs, ATMs/CDMs, ticket vending machines to name a few. These devices are operated through software interface which acts as a mode of interaction between the user and the system. But unfortunately, all these interfaces are designed considering right-handed population.

This paper particularly focusses on how a personal computer, i.e., desktop/laptop computer, is used by left-handed users. The objective here is to find whether left-handers struggle to perform a task or is it equally convenient for them to use the system. The efficiency of the task performed would also be an important factor to be considered here.

67.2 Background

The purpose of universal design is to design for everyone. While universal design is also known as inclusive design, design for all, it is sometimes also referred to as cross-disability access [1] so that the same product could be equally accessed by a differently abled person and does not feel emotionally separated from the world. Being a universal design, it also applies to normal human beings as well as those whose requirements are different even being a normal person. Universal design principles care for an additional range of user's abilities such as vision, motor skills, dexterity, speech, hearing, cognition, communication, upper and lower body strength, stature, balance, life span and a lot more to be the part of the mainstream [2].

The tacit aim of universal design is to improve the lives of end users as there could not be strictly one manner of using a product. Don Norman in his publication on general design and psychology critiqued that how in industries, designers are tasked with pleasing clients. The end users are not even taken into consideration, let alone the users with different requirements [3].

In case of user interfaces in digital systems too, it is extremely essential to take universal design into consideration. Software manufacturers try to implement this phenomenon by expanding their user base so that a diverse majority of users could be included. However, often it is not possible to cater the requirements of each and every user category. So, it is always better for software manufacturers to expand their user base by including few more user groups at a time to make the interface more inclusive.

67.3 Extreme User Bell Curve (Normal Distribution Curve)

While designing a product, it is the easiest to focus on the users who are right in front. But it is important to make sure to look toward the extremes of the potential user base. These user groups are represented in normal distribution curve at the extreme ends of the curve (Fig. 67.1).

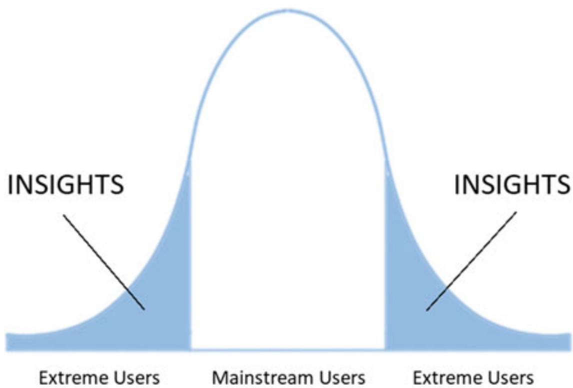
This curve is popularly called as usability bell curve or extreme user bell curve in the field of user experience design. The extreme user is most in tune with their needs, emotions and behavior. Understanding their needs can provide insights into the product to be designed. It is said that if requirement of extreme user is fulfilled, requirements of most of the users can be fulfilled much easily.

Although it is impossible to appease all of the extreme users, the inspiration and insights collected from them are valid for the majority of the mainstream user base [4].

67.4 Purpose of Study

This study is to understand the affordability issue faced by the left-handers in a computer interface. More than 10% of the human population is left-handed [5]. But a little attention is paid to cater the requirements of this user category. Taking personal computing into consideration, an average user spends more than 6 h daily with computers [6], which include both right- and left-handed users. However, the number of hours spent with computers is quickly decreasing with smartphones disrupting the industry as they are now capable of handling most of the day-to-day activities which were earlier exclusive to desktop/laptop computing. Although, a lot of professional work can only be performed using a Desktop/Laptop computing due to high graphics and performance requirements.

Fig. 67.1 Extreme user bell curve



Despite the above-mentioned fact, it is surprising to find that negligible percentage of left-handers use their dominant hand for input functions worldwide. They even use the computer mouse with their right hands, let alone a left-handed keyboard. Pointing is a precise task and requires fine motor skills. Therefore, it is meant to be used by one's dominant hand. Therefore, it was crucial for discovering the reason behind the whole scenario.

67.5 Self-assessment

Being curious about the fact, one of the co-authors self-tested the usability of the mouse by altering the dexterity of it from right-handed to left-handed and spending a generous amount of time with it using left hand. Two operating systems were used which include Microsoft Windows 10 and Apple Mac OS X 10.11.6. The major issue found here was that accessibility to mouse pointer customization setting was not simple and even when the functionality of the mouse buttons was altered, the orientation of the mouse pointer remained unchanged, i.e., left-tilted mouse pointer instead of right. The mouse pointer could not be manually oriented to an arrow pointing right via the cursor scheme option either (Fig. 67.2).

Apart from these, it was strange to discover that even when mouse configuration was changed to left-handed settings in Windows 10 operating system, the same settings did not prevail in the lock screen.

67.6 Research Problem

The lack of good design solution to dexterity in operating system interfaces is a big usability issue. The question which arises here is why this gap is overlooked at till date? Conducting a usability research may provide a better understanding about the shortcomings.

Fig. 67.2 Orientation of the mouse pointer does not change on left-handed mouse setting

67.7 User Interview

A casual interview was conducted with eight participants who happened to be left-handers. The objective here was to understand the behavioral pattern of them.

The following questions were inquired to the respondents:

Q1 What hand do you use your computer mouse with?
Q2 What is your present age?
Q3 What age were you introduced to a computer mouse?
Q4 Were you ever curious about using the computer mouse with your dominant hand?
Q5 Are you aware that left-handed cursor settings are available?
Q6 Have you ever changed your mouse settings?
Q7 Would you like to use the computer mouse with your left hand in the future?
Q8 Would you recommend left-handed beginners to use the computer mouse with their left hand?

Response to the questions is provided in Table 67.1.

Contextual inquiry was not conducted as the participants themselves could not state the problem they face while using the mouse with their right hand since they were accustomed to use the mouse in such a manner.

There was no meaning of asking the interview participants to use the mouse with their left hand and perform tasks since they were adapted to use the mouse with their right hand from beginning.

67.8 Findings

The senior most participant of the interview was a good candidate to inquire about the learning experience being introduced to computers at the age of 35. According to him, it takes substantial amount of time to train the non-dominant hand for mouse handling. This participant is using the default mouse settings since being introduced to computing interface and was not aware of the fact that left-handed setting existed.

Table 67.1 Interview response

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
P1	Right	21	5	Yes	Yes	Yes	No	Yes
P2	Right	57	35	Yes	No	No	No	Yes
P3	Right	28	7	Yes	Yes	No	No	Yes
P4	Right	31	13	Yes	Yes	Yes	No	Yes
P5	Right	32	10	Yes	No	No	No	Yes
P6	Right	28	7	Yes	Yes	No	No	Yes
P7	Right	29	8	Yes	Yes	No	No	Yes
P8	Right	25	7	No	No	No	No	Yes

It was surprising to hear from the respondents that nobody was interested in using the mouse with their dominant hand in the future including the two participants who have tried configuring it to left-handed mouse settings. On further asking to know the reason behind this, they stated that a substantial amount of time is required for training to improve the fine motor skill for mouse handling and now since they are adapted to the right-handed mouse setting, they are not willing enough to go through the cumbersome process of training the other hand all over again.

The two participants who tried configuring to left handed mouse settings were asked that why did they switch back to the normal settings to which they responded that by the time they learned about the they were already accustomed to the default mouse setting and above all it was difficult for them to keep the settings intact in the personal computer since the interface was being shared with all members of the family and anyway they had to use the right handed mouse while using public computers in school, cyber-cafes and elsewhere.

67.9 Insights

People are generally introduced to computer mouse in their childhood, when they begin to use computers either in their homes or in schools as a part of coursework. They use the mouse with their right hand since they are shown to do so and also find others use it with their right hands. By the time, the curiosity arises in their minds or/and they recognize that there are settings available for left-handed users, it is too late, and they are already accustomed to use the mouse with their right hand. Even changing the configuration settings to left-handed is a complex process, and it is a tedious task to switch between left and right mouse settings frequently, especially in case of the computer being shared by multiple users. Computers are also a part of sharable interfaces, meaning each system being consumed by multiple users at different time slots. This makes the process more complex as users cannot permanently keep left-handed mouse settings. Changing the settings each time is a time-consuming task which forces users against left-handed mouse usage.

67.10 Experiment

It was impossible to judge the efficiency of left-handed users using a disoriented mouse pointer on screen as discovered in Sect. 67.5, since they do not use the mouse with their dominant hand. Therefore, to measure efficiency of task performance, an experiment was conducted with reverse research methodology, where right-handers were asked to perform tasks with a mouse pointer tilted toward right side instead of left.

The experiment was designed. Fifteen tasks were sectioned into three parts. The 1st section with low precision selection tasks which had effective selection area of less than 30,000 square pixels, 2nd section with moderate precision selection tasks with effective selection area of less than 6500 square pixels and 3rd section with high precision selection tasks with effective selection area less than 150 square pixels. All sections contained five tasks each.

Participants were asked to perform the tasks with standard mouse pointer (left-tilted) and then perform the same tasks with a mirrored mouse pointer (right-tilted). The mirrored mouse pointer was specially created for the purpose of experiment and had exact same dimensions as the right-handed mouse pointer. Only the orientation was altered according to the likes of a left-handed user.

The operating system used here was Microsoft Windows 10. Two free attempts were given so that the user quickly becomes familiar with the task to be performed. It was also ensured that the mouse pointer rested at the same location before starting a task.

Time was recorded against each task performed by participants with both mouse pointers, and the following was the data collected:

The tasks to be performed were:

67.10.1 Section 1

- Open Calculator App and add 19 + 57.
- Open Web browser and navigate to Amazon.in.
- Go to Pictures directory and open file "Painting."
- Open Microsoft Store.
- Open Microsoft PowerPoint and add a New Slide.

67.10.2 Section 2

- Decrease the system volume from 100 to 50.
- Go to Pictures directory and open an image file with Photos App.
- Open Microsoft Word, and write your first name. Then change the font to "Times New Roman" and change the font size to 50.
- Open Chrome browser, and go to settings > proxy settings.
- Open Task View, and use the scroll bar to scroll down to the bottom of the page.

67.10.3 Section 3

- Open Microsoft Word Application and zoom down to minimum value (100 to 10%) by dragging the scroll tab.
- Open Adobe Photoshop Application and turn off the layer visibility.
- Open Adobe Illustrator Application and expand the panels from the right side.
- Open Google search, type the word “interface,” and navigate to the ninth page from the listings at the bottom.
- Navigate to Youtube.com on the Web browser, copy the text labeled “IN” above the logo, and paste it on a word processor.

Table 67.2 shows the results of task performance of a single participant. It could be clearly seen from the data that the disoriented mouse pointer produced decreased efficiency.

Graph shown in Fig. 67.3 depicts that there was a certain loss of efficiency when participants were performing tasks with the disoriented mouse pointer. This became even worse in the case of high precision tasks.

Due to the space constraints of the paper, only the results of the high precision tasks performed by the 15 participants are provided since a prominent difference of efficiency was reflected when visually opposite mouse pointers were compared while performing high precision tasks as seen in the graph (Fig. 67.3).

Therefore, it would not be wrong to say that a left-hander will face the same problem using a right-handed mouse pointer as how right-handers are facing problem using a left-handed mouse pointer even if he configures the mouse buttons accordingly.

Table 67.3 shows the results in the form of time taken by the participants to perform each high precision task with mouse pointers of both orientations. The additional time consumed by participants to perform each high precision task using

Table 67.2 Low precision, moderate precision and high precision task performance results for both mouse pointer orientations

Task precision	Mouse orientation	Task 1	Task 2	Task 3	Task 4	Task 5	Total time
Low		6.67	11.89	7.0	1.34	3.73	30.63
Moderate		6.52	8.05	15.74	9.66	4.36	44.33
High		3.15	2.74	2.31	6.90	24.21	39.31
Low		7.46	11.89	7.24	1.33	3.52	31.44
Moderate		7.16	8.76	16.55	12.94	5.15	50.56
High		5.16	3.23	3.25	9.43	28.48	49.55

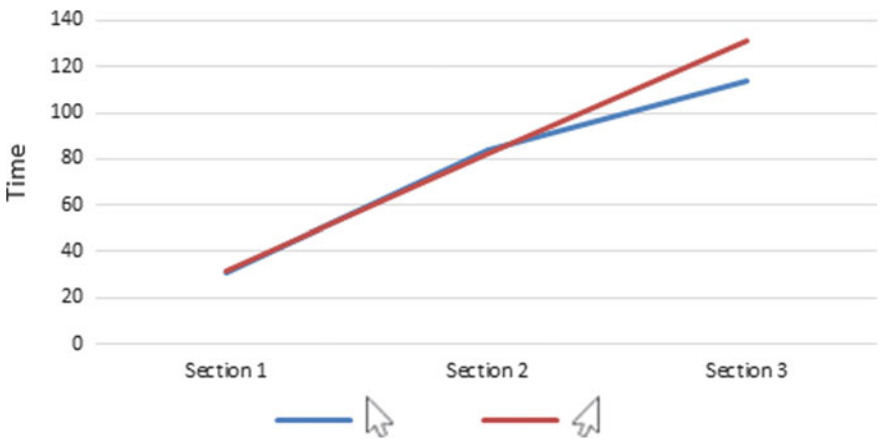


Fig. 67.3 Performance comparison graph

disoriented mouse pointer is calculated and converted into percentile. The mean provides the percentage of additional time consumed by each participant.

The graph (Fig. 67.4) shows the percentile scores of individual participants. We found that the participants on an average consumed 12.33% more time for a precision task while using a disoriented mouse pointer. To validate this point further, three participants from the initial interview were asked to perform the same tasks to check whether there is any difference in performance. Provided the fact that these participants also use the computer mouse with their right hands (Table. 67.4).

But this experiment yielded the same results as the experiment conducted on right-handers. On calculating the average of three participants, they consumed 10.25% more time for performing precision tasks while using the disoriented mouse.

67.11 Concept Design

Keeping the existing design problems as well as the above results in mind, a concept design is proposed for Windows operating system. This user interface design is inspired by the keyboard accessibility option which is provided in the Windows 10 interface. A mouse configuration option could be provided in the notification tray, and the dexterity of the mouse could be changed with a single button click (Fig. 67.5). A quick toggle option could also be provided with the help of shortcut keys as in keyboard accessibility option. This eliminates the hassle of configuring the mouse handling via the control panel application which is a cumbersome process leading to aversion among left-handed users particularly in case of using sharable interfaces due to the constant need of switching between two configuration settings.

Table 67.3 Comparison of mouse pointers for high precision tasks by 15 participants

P	Mouse orientation	Task 1	Task 2	Task 3	Task 4	Task 5	% of average add. time
1		3.15	2.74	2.31	6.9	24.21	
		5.16	3.23	3.25	9.43	28.48	
	% time	38.95	15.17	28.92	26.83	14.99	24.97
2		7.47	3.37	3.55	11.78	11.24	
		7.13	4.01	4.24	12.28	14.31	
	% time	−4.77	15.96	16.27	4.07	21.45	10.60
3		3.34	3.56	3.71	9.93	13.36	
		3.8	4.07	3.88	10.6	15.42	
	% time	12.11	12.53	4.38	6.32	13.36	9.74
4		6.46	5.97	6.22	13.96	15.23	
		7.34	5.97	6.41	13.68	17.79	
	% time	11.99	0.00	2.96	−2.05	14.39	5.46
5		4.38	3.27	3.61	10.95	16.11	
		4.95	3.7	4.34	10.48	19.19	
	% time	11.52	11.62	16.82	−4.48	16.05	10.30
6		4.81	4.35	3.65	10.6	16.83	
		5.85	5.3	4.46	12.42	16.34	
	% time	17.78	17.92	18.16	14.65	−3.00	13.10
7		3.87	5.86	7.87	8.21	14.86	
		5.74	3.87	9.96	12.23	20.4	
	% time	32.58	−51.42	20.98	32.87	27.16	12.43
8		3.34	3.24	3.18	7.13	7.35	
		4.11	3.38	4.24	7.35	15.7	
	% time	18.73	4.14	25.00	2.99	53.18	20.81
9		4.12	3.26	4.5	15.33	14.63	
		5.85	4.17	5.91	11.51	14.96	
	% time	29.57	21.82	23.86	−33.19	2.21	8.85
10		3	3.88	3.46	10.28	16.64	
		4.31	3.69	4.3	9.76	15.29	
	% time	30.39	−5.15	19.53	−5.33	−8.83	6.12
11		5.59	5.26	6.23	11.5	17.18	
		6.12	5.71	8.11	12.98	19.05	
	% time	8.66	7.88	23.18	11.40	9.82	12.19

(continued)

Table 67.3 (continued)

P	Mouse orientation	Task 1	Task 2	Task 3	Task 4	Task 5	% of average add. time
12		6.29	5.61	6.98	12.55	27.49	
		7.9	6.08	8.27	14.49	32.15	
	% time	20.38	7.73	15.60	13.39	14.49	14.32
13		3.21	3.79	3.61	9.25	9.89	
		3.59	3.87	3.93	10.11	11.05	
	% time	10.58	2.07	8.14	8.51	10.50	7.96
14		5.86	4.24	4.39	10.61	16.43	
		6.51	5.19	5.7	11.67	17.89	
	% time	9.98	18.30	22.98	9.08	8.16	13.70
15		4.55	5.17	4.48	11.82	16.26	
		6.36	5.64	5.34	13.57	17.52	
	% time	28.46	8.33	16.10	12.90	7.19	14.60

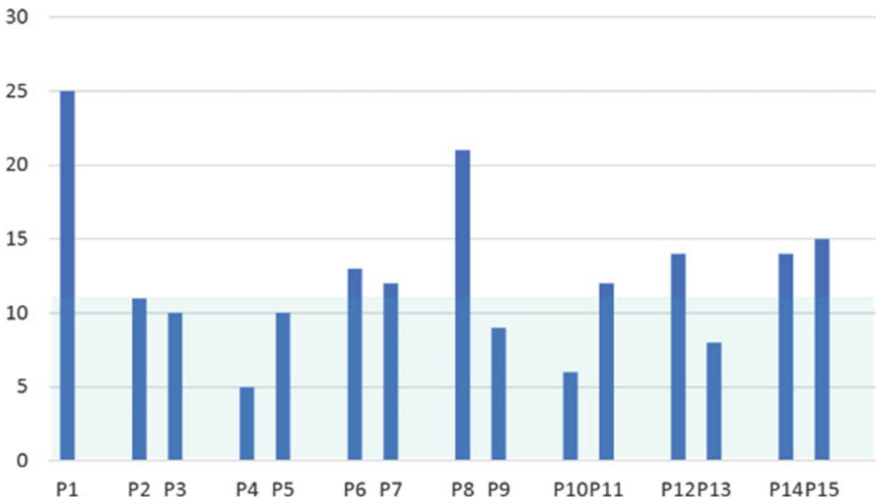


Fig. 67.4 Percentage of additional time consumed by participants while performing precision tasks

It is easily discoverable too. One could even accidently find it, become aware and spread awareness as well (Fig. 67.6).

Although this is a concept design and no design process are followed here. But should be an interesting and essential design project to work on in the near future.

Table 67.4 Comparison of mouse pointers for high precision tasks by three left-dominant participants

P	Mouse orientation	Task 1	Task 2	Task 3	Task 4	Task 5	% of average add. time
1		5.75	3.98	5.46	9.76	16.24	
		6.31	5.69	5.39	11.50	17.58	
	% time	8.87	30.05	−1.29	15.13	7.62	12.07
2		6.89	5.12	7.35	11.29	19.08	
		8.12	5.21	8.01	12.89	22.05	
	% time	15.14	1.72	8.23	12.41	13.46	10.19
3		5.29	6.61	7.93	12.25	18.15	
		7.95	6.05	8.12	13.28	19.79	
	% time	33.45	−9.25	2.33	7.75	8.28	8.51

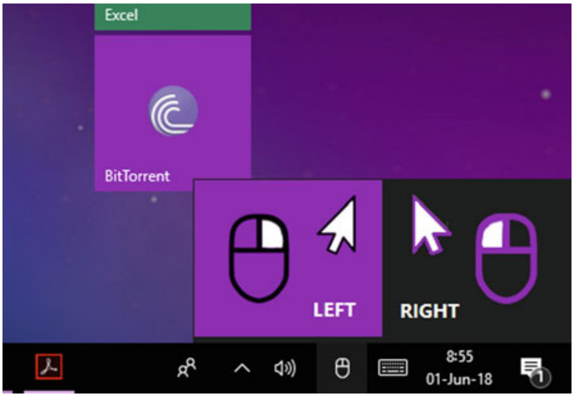


Fig. 67.5 Concept mouse accessibility option

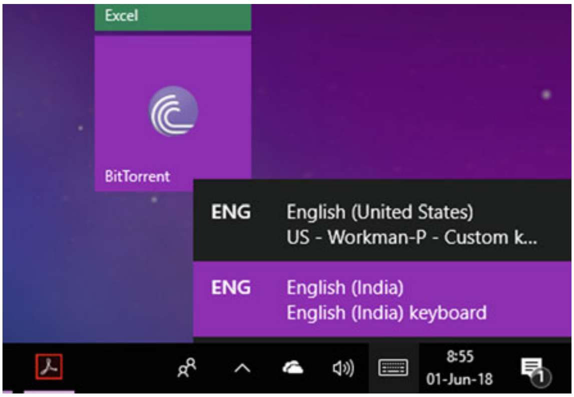


Fig. 67.6 Keyboard accessibility and switching option in Windows 10 OS

67.12 Conclusion

By analyzing the data collected from the experiment conducted, it could be concluded that for dominant left-handed users, using a computer mouse with left hand is an inconvenient activity in a computer interface since the disoriented mouse causes visual discomfort even if the mouse pointer is configured to left-handed setting. Also, the overall procedure of discovering, configuring and using the left-handed mouse in itself is very unintuitive. There is a loss of efficiency in performance while using a disoriented mouse pointer particularly when dealing with high precision tasks.

The major dexterity issue that left-handers face while accessing a computer interface is at the stage when they are introduced to the personal computers. There is a lack of awareness among computer users about this issue. Being a beginner, a user is not aware of the fact that the mouse could be configured according to one's necessities. Another big problem is to do with the sharable interfaces, a lot of time is consumed in configuring the mouse to left-handed settings and vice versa via control panel. Software manufacturers are not keen enough to provide a quick switching between left- and right-handed mouses. It has been 45 years since the advent of personal computers and graphical user interface. Attention must now be paid by the user experience designers to resolve this issue. Just because users can get adapted to the interface does not mean that we should not provide options to them.

67.13 Future Scopes

It would be interesting to study the behavior performance of the users who use their left hand as the primary driver for using mouse. Further objective would be to study and compare the behavior of users with ambiguous dexterity. The orientation of other visual elements in an interface such as icon placement, menu system, browser tabs, scroll bar and windowing buttons is another area of research to be conducted as a part of larger study. It would also be an interesting area of research to educate beginners on this issue. Interface design problem requires an enormous user research too.

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Part VII
Design Collaboration and Communication

Chapter 68
Extending Service Blueprint for New Age Services

Sylvan Lobo, Shivani Sharma, Ulemba Hirom, Ravi Mahamuni and Pramod Khambete

Abstract A service blueprint (SBP) is a powerful representation tool which depicts critical aspects of service encounters—the basic building blocks of a service. It helps to understand the current service encounters and to specify the designed service. For the conventional service blueprint, today's new age services can bring in various complexities affecting effective representation, clarity, and expression. While various service blueprint representations are evolving to address these challenges, in this paper, we discuss some challenges that we encountered in a 'research-through-design' study while designing an employee onboarding service. This included service situations such as highly granular interconnected interactions, technology-enabled multi-channel interactions, recurrence of similar interactions, and others. We arrived at a scheme of representations and notations which was iteratively applied in the onboarding service design. We present a preliminary evaluation of the representations and notations through a survey with 65 participants. The findings would be relevant to design practitioners, researchers, and professionals in the field of service management.

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68.1 Introduction

SBP [1] is a model and visual representation of the service delivery process, primarily from the customer's perspective. It shows the flow of service encounters depicting customer interactions with touchpoints, connections between activities at various stages of service encounters, and internal support activities. It highlights customer actions, contact employee actions, back-end employee actions, support processes, and physical evidences. It also visualizes intangible experiences, which is the core of user-centric service design. It depicts the service holistically to highlight interconnections and dependencies between service components, technology, and operations.

Service delivery was simpler in the past, with service encounters usually occurring in short single sessions within a physical environment, that is, in-store or over the phone for certain durations only. However, new age services are becoming increasingly complex with the changing technological trends and raised customer expectations. The traditional format of the SBP may not be sufficient to represent the complex new age services. In order to be a more effective aid for communication and analysis, it is important to consider visual representation aspects of an SBP. In this paper, we discuss some of the representational limitations we encountered with the basic SBP, in a research-through-design study while designing an employee onboarding service. We arrived at potential representations to address the issues that we faced, and assessed these through a survey. Through these representations, we aim at easy understanding and analysis of SBP by multi-disciplinary service design teams.

68.2 Background

SBPs remain widely adopted in service design despite the existence of modeling tools such as UML [2] and BPMN [3, 4]. SBP was arguably the first attempt to view service encounters from a customer's perspective [5]. Its flexible and versatile nature [6] rather than the use of standardized notation has been a key to its sustained adoption. Over the years, service blueprints have been evolving [7, 8] both visually and structurally, although still mostly made up of text laid out in a grid-like structure, often sticky notes.

The concept proposed by Shostack [5] highlighted the benefits of the diagram to bring the focus on the customer and intangibility in services [5, 9]. The structure initially separated onstage and backstage activities. Kingman-Brundage et al. [10] and Bitner et al. [6, 7] were influential in developing the SBP, leading to the use of two axes and multiple lines to separate interactions into layers. The x-axis shows the sequence of activities that take place in the service encounter till its completion. The y-axis depicts interactions among customers, touchpoints, and other entities as the encounter progresses. The y-axis is layered into swim lanes creating rows, where the upper rows inform about the customer, their activities and environment, physical evidences, and the touchpoints that they interact with. The lower layers represent the service provider activities. Vertical slices represent how the customer interacts with the service at different stages of the encounter, detailing interactions with the front-facing staff, backstage staff, back-end activities and systems. Layers of the service are separated by lines: (1) 'line of interaction' across which the service provider (front-stage employee or system) and customer interact, (2) 'line of visibility' beyond which activities are not visible to the customer, and (3) 'line of internal interaction' which separates out support processes. The layers include 'physical evidence,' 'customer actions,' 'onstage employee actions,' 'backstage employee actions,' and 'support processes' [6]. Information is usually laid out as blocks of text in a grid-like structure within layers, connected to each other by arrows depicting the flow of interactions and interdependency between various steps involved in the encounter. Figure 68.1 is an example of this structure popularly used today. Adaptations exist; for example, Polaine et al. [11] have refined the axes and layered representation of the SBP further and introduced the phases such as 'aware,' 'join,' 'use,' 'develop,' and 'leave.'

Many intricacies were introduced to represent better customer orientation, such as capturing the customer experience [6], physical and virtual spaces [12], emotions [13], and multiple channels [14]. Herzberger et al. [15] and Schenkl et al. [16] review literature in product-service system (PSS) and business modeling and discuss a systematic and interactive approach called PSS life cycle to model and evaluate a PSS. It focuses on product functions rather than physical representation. Visual mechanisms were explored to convey intangible aspects such as experience, emotions, and behavior [17], or toward expressiveness with graphics and novel mechanisms similar to musical notation [18, 19]. Polaine adds motivational and emotional aspects to the visualization in her proposed Blueprint+ [20], while also improving graphical elements for better readability and effectiveness.

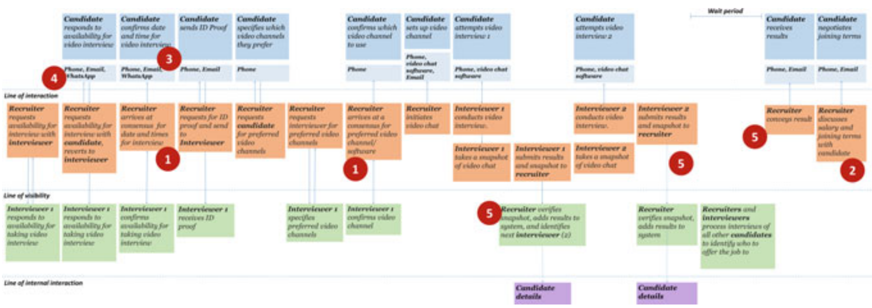


Fig. 68.1 Selection phase in the basic SBP format

68.3 Motivation

A basic [6] SBP was adequate for earlier services where service encounters were simpler in nature. Most services today are highly complex, use multiple non-human touchpoints and technology, and involve a large number of scenarios. In case of PSS, Schmidt et al. [21] highlight customer acceptance as a challenge with barriers including customer behaviors such as values, beliefs, irrationalities, as well as product attributes such as availability, costs, and complexities. Customers are more empowered, dictating various aspects of the service expecting an omni-channel experience, constant availability, and innovation [22]. Employees usually also have a high degree of latitude in their decisions and actions. Representing complex services can make the basic SBP format very dense, making diagnosis and analysis difficult.

In their thesis, Haugen [8] discusses some shortcomings of the SBP, highlighting that despite being structured, an SBP for complex services can be long and complicated, making it to be difficult for stakeholders to comprehend and analyze [8]. The issues are compounded with the participation of multi-disciplinary collaborators and stakeholders who may not have a common language to communicate or understand the diagram. SBP adaptations have been very textual in nature using rectangular blocks of text usually on colored sticky notes, connected by arrows, arranged like a grid in layers (Fig. 68.1). There is minimal graphics and visual hierarchy to help process what is important and what is not. Some annotations such as a circle shape with 'f' letter in it to highlight failure points [9] or a fan-like notation for complexity and divergence [23] have been utilized.

With evident shortcomings, identifying complex situations in new age services and extending the set of representation conventions could help manage complexity and enhance the communicative power of SBP, making the tool more effective for service designers and multi-disciplinary teams, while still maintaining versatility and flexibility.

68.4 Onboarding Service—Research-Through-Design Study

With the design of a hiring and onboarding service as a use case, our research goals were to identify challenges in the representation of new age services and to identify adequate representation mechanisms to address these in SBP. The team utilized a research-through-design (RTD) [24] approach for the study where they noted challenges encountered with creating an SBP, collectively reflected on them, and arrived at various solutions as listed in Sect. 68.5. The focus of the RTD was to inform our research on enhancing the SBP format, while also maintaining a focus on the end product of the design, i.e., improving the hiring and onboarding service [24].

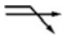
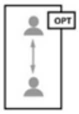
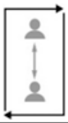
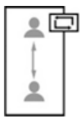
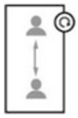
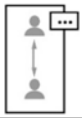
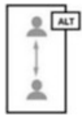
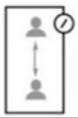
A multi-disciplinary participatory design team comprising service designers, user experience designers, and other stakeholders from a large IT organization collaborated toward designing the hiring and onboarding service for the parent organization. The service involved various phases, starting with an experienced candidate looking for a job, applying for a job, interviews, accepting an offer, participating in an induction program, and then joining a project team in the organization. Multiple SBPs were created to map the phases of the candidate life cycle. There was a high degree of variability in the customer journey and service, which involved multi-channel concurrent interactions spanning across a long time and involving multiple parties. This led to representation problems in the blueprint. The team listed situations where the basic SBP format seems inadequate and arrived at different solutions for each issue. These are listed in Sect. 68.5. For example, we found frequent to-and-fro interactions (Table 68.1 S1) between providers and customer which would be represented in the basic SBP by two-way arrows, which is not communicative enough. The team used creative exercises to arrive at multiple solutions with basis in communicating meaning through symbols and icons that closely conveyed the service situation. Solutions also had basis in existing familiar constructs such as UML. The focus for solution ideas was to communicate the intent of the representation clearly to multi-disciplinary teams. Through consensus, the team settled on at four different approaches for each issue and also refined them through a pilot survey.

We evaluated the representativeness of our notations through a survey with 65 IT professionals familiar with diagrams. This was done to root out ambiguity [25] and varied interpretations. The respondents were provided six service situations, each with four alternative notations. After a few pilot surveys, we arrived at sufficiently relevant set of notations. We then administered the survey with the 65 respondents, who ranked the four alternative notations for each service situation. They had to indicate the most suitable option followed by the next suitable options. They could also indicate symbols that were not representative at all by marking it with an 'X' and not ranking it. They could also comment and sketch other symbols which they felt may work better. Figure 68.1 shows an adapted phase of the service using the basic SBP format as specified in guides [26, 27], highlighting areas with representational difficulties. Figure 68.2 depicts the SBP again using our proposed representations and notations for blueprinting. Table 68.1 indicates the sets of notations we devised.

68.5 Service Situations and Their Proposed Solutions

Below, we list the service situations where the basic SBP representations may not be effective enough and also describe the corresponding proposed representations. At the beginning of each section below, we have highlighted in italics the specific situation that we wanted to depict in the service blueprint but found shortcomings. This is followed by a discussion, detailing the situation in our study, the issue in representation, and the proposed solution.

Table 68.1 Four symbol options for various service situations assessed in the survey

Service situation	1	2	3	4
S1: Highly granular interconnected interactions: The customer and service provider interact back and forth multiple times till consensus				
S2: Changes in context: The outcome is subject to change, in case of operational constraints				
S3: Delays: A back-end activity may cause delay in service delivery				
S4: Optional: The encounter may or may not take place				
S5: Recurrences: A similar encounter may repeat at another time in the service				
S6: Variations: There are other alternative approaches				
S7: Technology-enabled multi-channel interactions—Fig. 68.2a				
S8: Customer interactions outside service system—Fig. 68.2b				
S9: Varying roles of staff employees—human figures in Fig. 68.2c				

S1: Highly Granular Interconnected Interactions. *The front-stage staff negotiates with the candidate and internal staff (interviewers) to agree upon when to conduct the candidates' interview. A similar situation arises later to agree upon which software to use for the video interview* (Fig. 68.1, ***circle 1***). Service encounters often involve interactions which go back and forth between the customer and the provider. These multiple interactions can span a short duration or many days and be considered as logically closed when an agreement is arrived at. The service encounters may also involve interactions with many other touchpoints, where outcomes are intricately interconnected. In our study, for example, the candidates, staff, and interviewer would communicate over phone calls, emails, SMS, and other messengers till they decided a suitable interview date and video channel. Such complexities are often not clearly highlighted in current SBPs.

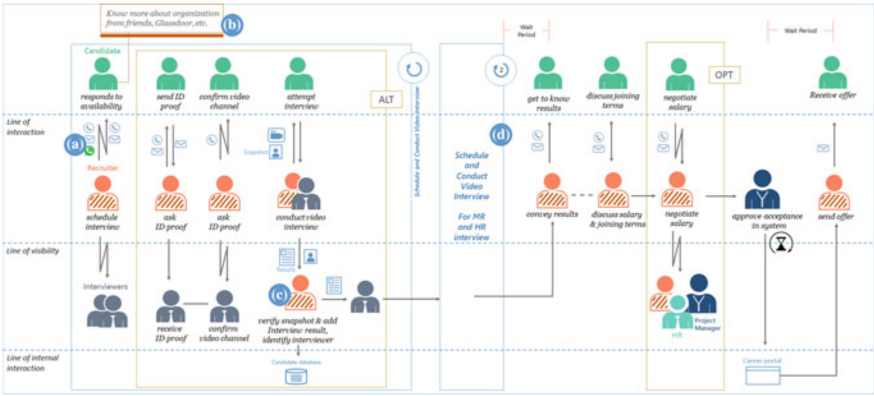


Fig. 68.2 Selection phase with proposed annotations

Although a two-way arrow (Fig. 68.1, **circle 1**) is a common way to depict that an agreement is required to proceed [27], this minimal representation may not highlight the rich complexity and effort. It would help if this complex situation is visible, so that the inefficiency may be addressed. In a similar situation, Shostack suggested a fan-like notation to depict the degree of latitude an employee had [23]). We indicated the reality of the engagement's complex nature by more variations of two-way arrows as shown in Table 68.1 (S1). While analyzing the blueprint, the notation can make readers realize that in reality the steps are much more granular and complex, while maintaining simplicity. Another symbol emerged from suggestions by survey respondents as shown in Fig. 68.4.

S2: Changes in Context. *In some cases, the work location communicated to the candidate in the selection phase could change upon joining due to business dynamics. Although this possibility is communicated to the candidate, it affects them if it does materialize* (Fig. 68.1, ***circle 2***). There are many such situations in service delivery, where there is potential for a context change, which can affect the customer's or even the provider's behavior and decision-making in a big way. Such situations can be difficult to predict, but it is possible to proactively mark where such changes in contexts can potentially originate.

The basic SBP does not highlight such situations, unless the designers choose to use annotations. At most, this is treated as a service breakdown at the point where the change occurs, which is subtly different from a potential change in context. Currently, notions such as fail points (circle with an F) or lightning symbols which are used in contextual design work models are utilized in blueprints to mark failure points. The use of such symbols should be maintained, but additionally, potential context changes can be appropriately marked where possible. We arrived as symbols as shown in Table 68.1 **(S2)**, to depict where a change in the context can originate or affect the customer. When an SBP is used to depict the current service, it is possible to identify and mark such points using inputs from the user research. Thus, adverse situations can be handled gracefully, for example, by training customer representatives to communicate or provide alternatives. This should be differentiated from service breakdowns which also include a service recovery plan. A change in context however can have either negative or positive implications to the customer and may not be entirely predictable. The need for such adaptations is also briefly suggested in [6] and [26].

S3: Indicating Sources of Delays. *We observed that although certain candidates were selected by the organization after interview, there was a considerable delay in rolling out an offer letter. This delay arose due to levels of approvals required internally.* Some internal activities may take a large amount of time to complete due to internal dependencies. This means the customer needs to wait for a considerable time. It will be good to indicate such potential sources of bottlenecks. A horizontal time bar at the top of the blueprint is often utilized to depict the overall time that the activity in the service may take, from the perspective of the user. However, what exactly is contributing to the delay is usually not immediately visible. We marked the key activities which are specifically impacting the wait time, using symbols as shown in Table 68.1 (**S3**).

S4: Optional Interactions. *Some candidates would choose to negotiate their salary, some would not. There were similar other optional service situations, such as calling for reminders or queries.* Certain parts of encounters in a service may only take place depending on certain conditions or choices that the customer may make. We explored using different mechanisms to indicate such optional courses of action (Table 68.1, **S4**).

S5: Recurrences of Similar Interactions. *The video interview is conducted three times with minimal variations—a technical round, a managerial round, and an HR round.* It may seem redundant to represent repetitive encounters in detail each time they occur in the service. Although sometimes referred to as patterns [7], there is no standard way to represent and reuse sections of an SBP. Flowcharts and other UML tools represent such reusable modules in an abstract square with a name. We propose similar approaches (Table 68.1 **S5**; Fig. 68.2d), where we encapsulate the first instance of a reusable module within a box, and subsequent references are shown as the box with a name and contain a very minimal highlight of the interactions that take place.

S6: Variations in the Encounter. *In the case study, an interview may be conducted in many different ways—in person, telephonic, or video.* The SBP often only shows a single path through the customer journey of a persona. It can be useful to indicate that there are variations in the way an encounter can take place. These variations can be shown separately, so as to not break the sequence of encounters. We explored different ways (Table 68.1, **S6**) to indicate that a set of interactions could take place in different ways.

S7: Technology-Enabled Multi-channel Interactions. *The recruiter initiates contact with the candidate using multiple channels such as email, chat messengers, and phone calls. The candidates can choose to respond by any mechanism like email or the job portal, while expecting to seamlessly switch between the mechanisms.* In technology-enabled interactions, the candidate may interact directly with non-human touchpoints, like the career portal or a mobile app. They also use multiple such channels to meet their objectives, expecting continuity and seamlessness over time. The customer dictates preference of the channel depending on personal choice and circumstances. For example, the customer may receive an SMS and email, but choose to respond through a telephone call or even a chat messenger. Such seamless transitions may be difficult to depict, as the means and the sequence of use are not predefined. It will be useful to show that such transitions exist, where they may occur and how to deal with them, for designing a better multi-channel or multi-touchpoint experience.

As shown in Fig. 68.1 **(circle 4)**, the basic SBP utilizes swim lanes for physical evidence [27], customer actions, and front-stage actions to describe the setting in which a customer interaction takes place. Although physical evidences highlight more than merely touchpoints, multi-channel interaction is not adequately evident. The physical evidence section usually simply lists touchpoints textually or through icons. Service blueprints were originally developed to map the process for primarily single channel (mostly human to human). As Patrício et al. [14] also highlight, an SBP does not adequately address the multi-channel nature of new services.

We depicted multi-channel interactions as shown in Fig. 68.2a to indicate which touchpoints and channels may be used during the interaction. Showing the touchpoints graphically near the arrows makes the touchpoints being used by the customer and staff, explicitly visible. In case of multiple touchpoints, they can be ordered by which may be most likely used or can be augmented by possible contexts the candidate may be in. Using two-way arrows also helps, where each arrow may have a different set of associated touchpoints. One set of touchpoints could be placed besides the arrow from provider to customer, and another set of touchpoints could be placed besides the arrow from customer to provider, since these two may require different communication channels.

S8: Customer Interactions Outside the Service System. *In the onboarding design study, there were many cases where the candidate interacted with his own ecosystem, that is, external third-party services.* A customer may engage with external services to make decisions about the service. For example, they may learn about a product from feedback and reviews on social media. Showing some of the key interactions that the customer has with his personal ecosystem can be useful, although such instances are not currently part of the service. Basic SBPs as represented in Fig. 68.1 (circle 3) do not show such interactions. Service engagements with external services are usually represented in the bottom-most layer beyond the line of interaction. Customer interactions outside the service system are rarely captured, the closest option being showing a servicescape or physical evidences. We annotated this as shown in Fig. 68.2b and can help demark the current service scope indicating which services it requires from outside to work holistically.

S9: Varying Roles of Staff Employees. *The recruiter engages with the interview beyond the line of visibility and later engages with the customer at the line of interaction. The same staff plays different roles at different times in the service.* In the lifetime of the service, the same staff employee plays different roles at different times. They sometimes directly engage with the customer and at other times engage only with other staff or systems internally. It will be useful to visualize and identify service issues and opportunities arising from how the staff operates. The current format of the blueprint uses different colored sticky notes or rectangles to represent staff at the various layers. Pinpointing staff roles simply on color may not be easy. How the staff switches across the layer to play different roles may not be clearly visible too. Thus, we portrayed each staff employee graphically as human figures as in Fig. 68.2c, so that the role the staff plays is immediately visible.

68.6 Observations and Discussion

Figure 68.3 summarizes the results of the survey, showing the overall ranking arrived at through Garrett's method [28]. It indicates how many respondents ranked each notation as rank 1 and how many rejected each notation as not indicative to the given scenario. The rank 1 preference is quite clear for all situations except for situation 2, where two notations are nearly equally preferred, and can be left to discretion of the team. Also, each set had at least one clear option that was rejected, except for situation S5. The respondents also discussed and shared comments and alternate annotations. Some respondents preferred the simplest variation among the options, considering that they expected the symbols would be drawn by hand. This could explain why option 1 of situation 1 performed better than option 3, which we felt could have been more indicative. Five respondents stated that the textual tags

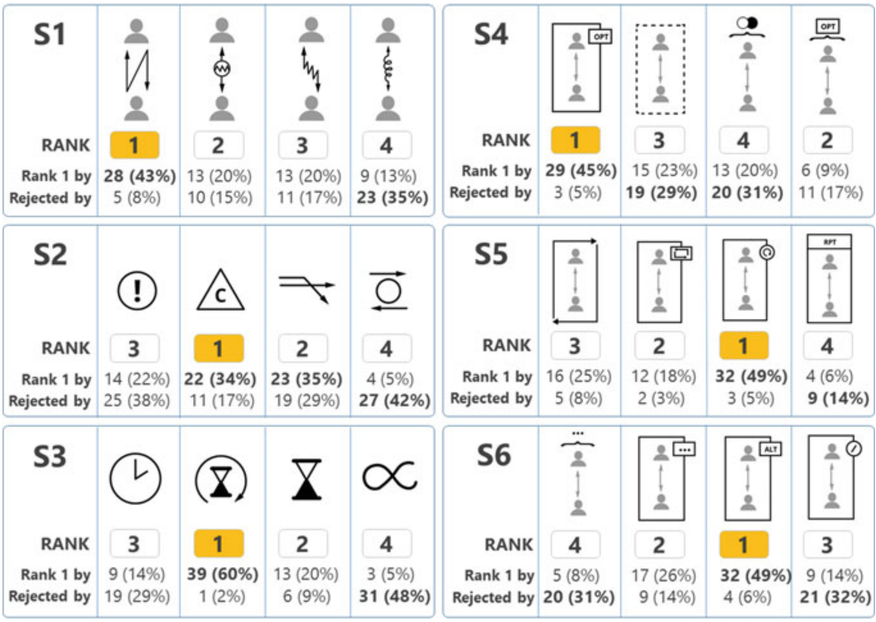
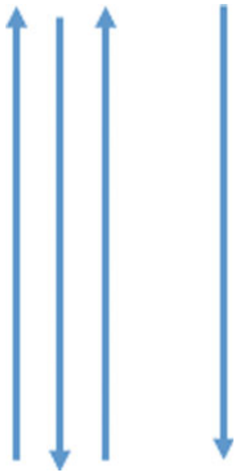


Fig. 68.3 Summary of survey results

Fig. 68.4 Alternate symbol for situation S1



within the notations provided a clearer indication compared to abstract symbols. They also felt the representations with boxes and textual tags followed a consistent template, while the rest were more symbolic and difficult to relate to. For situation 1, five respondents stated that multiple arrows could be used instead, as shown in Fig. 68.4, which seems elegant.

68.7 Conclusion and Future Work

While the blueprinting technique was found to be useful to portray and understand the existing services and proposed services, we experienced certain issues in representations while creating the SBP for a complex organizational service. As highlighted, our annotations or similar ones can help while creating a service blueprint to depict various service situations such as highly granular interconnected interactions among customers, touchpoints and back-end entities; technology-enabled multi-channel interaction; customer interactions outside the service; varying staff roles; and potential changes in contexts. We attempted to make the SBP representation of certain situations of such complex new age services, easy to read, understand and analyze, and identified the most suitable representations through a survey.

We arrived at multiple alternatives to depict these situations, and based on the first impressions, we find these annotations communicating the intent and situation without any major ambiguity. These initial findings about the users' preferences of the representativeness of the notations for service blueprinting could help progress toward a more unified set of symbols and icons and also be considered for other service design or PSS design mapping tools such as customer journey maps. The notations here are sufficiently representative for use in SBPs in similar service situations, although they can be evaluated and refined further through use in practical situations while creating the blueprints. As presented in the discussion above, it can be noted that the annotations should be simple to draw by hand, not orient too much toward the abstract symbolic, and can include textual constructs and a consistent visual language.

Many representation challenges still remain open, and the SBP can benefit from further exploration in effective visual communication capability. The proposed notations can be refined further through more practical applications in more projects, and a more consistent and unifying set of symbols can be arrived at.

68.8 Limitations

The solutions presented here have not been yet been tested for suitability across other service design blueprinting case studies. Also, the annotations have been primarily evaluated by IT employees with exposure to diagramming. This may not cover all stakeholders with varied other backgrounds often present in service design projects.

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Chapter 69
Agile Development of Physical Products —A Case Study of Medical Device Product Development

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Abstract Agile development gets more and more relevant in non-IT development processes. Main reasons are the flexibility and the shorter reaction times. The different conditions of physical products compared to software products are current challenges for the use of agile product development methods. This project focuses especially on a medical product development by using scrum to develop agile. After each sprint, the scrum process was adapted to the respective circumstances. Additionally, the team participated a survey, which focuses on collaboration and team behaviour aspects. The survey is based on the team climate inventory. Results of the research were amongst others a 3D-printed microtiter plate, best practices for scrum in medical device development and the survey. Based on the implementation of agile methods in this project and the survey, a recommendation model of an agile medical device development is derived.

69.1 Introduction

The current challenges for product and software development include digitalization and globalization [1, 2]. This results in a new, stronger orientation towards the customer. Their desires change often and many needs are subconscious. Agile methods, such as Scrum and Design Thinking, already offer solutions for these challenges in software development [3].

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The study "Status Quo Agile" shows, that physical product development same as software development also benefits from agile techniques [4]. However, the transformation from digital to hardware products requires suitable adaptations.

The development of medical devices with opportunities through additive manufacturing processes, data analysis, and virtual reality on the one hand and limits through strict regulations on procedures and documentation on the other hand is a special sub-area for agile product development. The special sub-area allows fast prototyping, but it does not allow a non-document process.

In the described project, the development of a microtiter plate is tracked. The focus of this paper is the adaptation of scrum to the conditions of the product development of a microtiter plate and the analysis of team satisfaction changes during the process. Thereby, Scrum is an agile project management process with roles, artefacts, and methods [5]. The goal of the adaption is an agile process which is more specific and better suitable for a physical product development than the original scrum.

69.2 Research Methodology

The Design Research Methodology (DRM) according to Blessing and Chakrabarti is used as a guideline to structure this paper [6]. They propose a procedure divided into four phases, in which iterations are possible depending on the project type.

The research clarification phase serves to clarify the research objective. In this paper, the gaps in the state of research were identified by an initial literature research [6]. The relevant research fields are agile product development, medical product development, and team climate inventory. This led to the objectives of the paper and the student research project, which are reflected in the research questions (Sect. 3.4). The second or descriptive phase establishes a detailed understanding of the field of research. In this paper, the findings of the descriptive phase are documented in the section on agile and medical product development.

In the prescriptive study, concrete solutions for the introduction of agile methods into the development team were selected and applied. This is described in Sect. 5.1. The results of the evaluation of these adaptions during the descriptive part II are documented in the feedback log and the results of the psychometric survey in Sects. 5.2 and 5.3.

69.3 Literature Background

This section introduces the theoretical background of the relevant topics. Agile development is introduced and especially scrum is focused. Medical product development is explained with focus on the basis of its requirements on the development process. Moreover, the team climate inventory for the evaluation of the survey presented.

69.3.1 Agile Product Development

Agile Product development is an approach which prefers flexibility and improvement during a smaller process to linearly rigid planning and processing. Takeuchi and Nonaka first described such practices in successful companies in Japan and North America. They called it "rugby approach", as they identified parallels to the sport with its interruptions in the game and the reorientation of the teams [7].

The founders of the Agile Alliance met in 2001 to form a common basis for agile methods in the agile manifesto. The essential values are described as follows: "Individuals and interactions over processes and tools. Working software over comprehensive documentation. Customer collaboration over contract negotiation. Responding to change over following a plan" [8].

The most famous agile method is Scrum. It is an agile method, which was developed by Schwaber and Sutherland and divides the project into several sprints. In each sprint, the team is divided into roles and creates product increments [5]. The team is composed of three roles [9]: the product owner is responsible for the work result and the external representation. The scrum master as agile process agent has to support the team on project management level, moderates the meetings, and supports the team work. The development team as a self-organized unit is responsible for the design of the product.

A sprint is organized into phases. The sprint planning is used to plan a sprint at the beginning. The daily scrums are short, daily meetings. At the end of a sprint, a product increment is evaluated by the customer as a potentially shippable product in the sprint review [10].

Finally, in the sprint retrospective, the team evaluates and improves the way they work before they start a new sprint with the feedback from the team and the customer [5]. User stories serve as the central communication unit. They consist of users, features, and benefits of a specific product function. The user stories are used on the one hand to structure work packages and on the other hand to prioritize customer requirements [11].

69.3.2 Medical Product Development and Microtiter Plate

Medical products have a direct influence on the patient's life and health. Transparency and a comprehensible and complete documentation are mandatory by the Medical Devices Act (MPG) and related standards in Germany [12]. The documentation requirements are not limited to the finished product, they also include the development and production process [13].

The devices considered in this research are microtiter plates. They are sample containers for laboratory instruments consisting of several reaction vessels, so-called cavities. Designs for six up to several hundred individual vessels are possible. They are applied in high-throughput screening (HTS) for investigations in clinical diagnostics, molecular, and cell biology, food analysis, and pharmaceutical research [14].

69.3.3 Team climate Inventory

The team climate inventory (TCI) is a survey based on the four-factor theory by West [15]. In 44 questions, the self-estimation of a team will be queried to the factors *vision, task-orientation, participative safety,* and *support for innovation* with respective subfactors [16].

The vision in the team climate inventory unites clarity, appreciation, unity, and accessibility. Task-orientation represents the team's ability to reflect and its claim to question its results and processes as well as to optimize them, if necessary. The cooperation is described by the factor participation security for communication values and for the emotional contact with each other. Support for innovation describes the active attitude of external project participants, who also influence the willingness and support of the project [15].

To calculate the individual subscales, the individual questions are added together in specific patterns (see [17]). The sums of the checked values (1–5 from low to high) are then averaged over the team surveyed for all subscales. The values of the four factors consist of the sum of the respective subscales.

The used version was translated and performed by $n = 810$ persons in $N = 149$ teams, whose results were assessed as significant (cf. [17]).

69.3.4 Research Question

Based on the literature review and the gaps identified in Sect. 3.1 to 3.3 are defined and will be answered in Sect. 69.6:

(Q1) How do agile methodologies influence the team climate in student research projects?

(Q2) Which adaptions and changes to agile methods like scrum support effectiveness and a comfortable working environment?

69.4 The Project and Boundary Conditions

The project interdisciplinary agile medical technology product development (IDAGMED) sets the framework for the investigation of the compatibility of agile methods with medical product development. Various disciplines such as simulation and design work together on the further development of an intelligent microtiter plate.

The team in the six-month phase consisted of seven members including a responsible person for design, simulation, requirements management, and agile procedures. The design task includes a design adapted to additive manufacturing processes considering the requirements of fluidics. The focus of the simulation is the analysis of the resulting flow and the derivation of improvement measures for the geometry. The combination of classic and agile requirements management had to take medical guidelines into account. Furthermore, the material selection for biocompatible microtiter plates was necessary.

The team was supported by auxiliary scientists who took organizational tasks and are regarded as equal team members. The team had access to the work environment of an institute and the makerspace.[1]

69.5 Realization of the Medical Product Development

This section describes the final product results followed by impressions of teamwork and adaptions within the sprints.

69.5.1 Product Results

In addition to numerous research results, simulations, and economic considerations, the following 3D-printed prototype represents the final product results of the 6-month project. So far it has been improved by a new geometry to enable more cell-friendly microfluidics, which were simulated in various runs. Stereolithography was used as the manufacturing technology, and numerous analyses and benchmarks were conducted for its applicability. The new microtiter plate is shown in Fig. 69.1a, b.

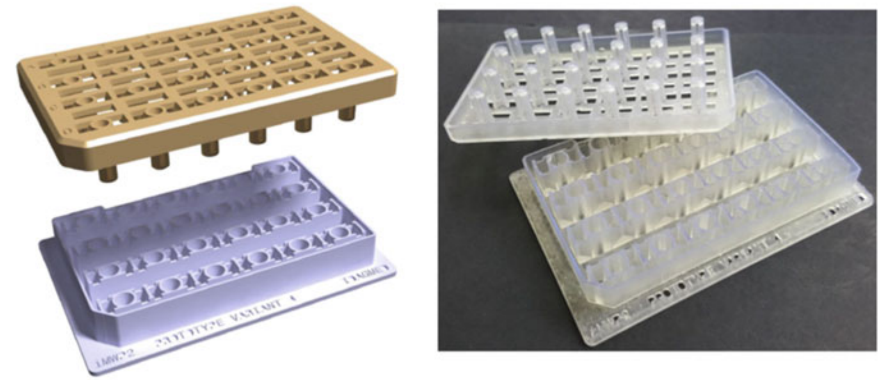
69.5.2 Impressions of the Sprints

The following section contains general impressions and selected derived measures of the IDAGMED project.

During the first sprints in an interactive workshop/simulation game, the introduction of the daily scrum provided the basic knowledge and the environment for agile work. The daily scrum was introduced via Slack,[2] but developed into video chats or on-site meetings that were much more efficient.

[1]Innovation Hub in Munich, Germany. https://www.maker-space.de.

[2]Online Communication Tool, https://slack.com.



(a) CAD model of developed plate (b) 3D printed microtitre plate

Fig. 69.1 Project results

Fig. 69.2 Sprint impressions

Retrospectives consisted of a short motivation, an event timeline for joint event identification and the subsequent evaluation of previous or future improvement potentials. In addition, during the following retrospectives, tools such as a more detailed user story mapping (see Fig. 69.2a), Starfish retrospective (see Fig. 69.2b), timeboxing, feedback pitches, and joint visualization of the share emotional perception (see Fig. 69.2c) were used.

One of the early retrospectives showed that the goal of the development was still unclear at the beginning. Therefore, a common vision in the form of an agile vision board was written (Fig. 69.3a). In addition to the overall vision, it also includes the product to be manufactured, the user, and the goals. The visions for the individual sprints were defined out as shown in Fig. 69.3b.

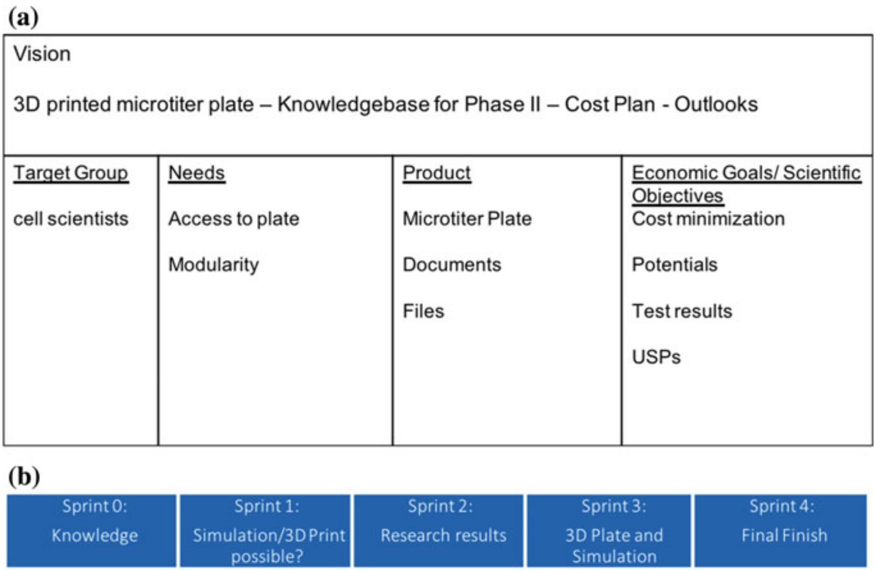


Fig. 69.3 **a** Agile Vision Board, **b** sprint visions

69.6 TCI Results and Evaluation

This section answers the research question Q1 in 6.1 and in 6.2 presents recommendations on research question (Q2).

69.6.1 TCI Results

Figure 69.4 shows an overview of the self-assessment measured with the TCI. After an optimistic initial assessment, the values in the January survey fall sharply and then rise again until the end of the phase. Only the vision exceeds the initial values.

The early prototypes at the beginning of the development task supported by Scrum and the rapid prototypes with additive manufacturing promote the assessment of the first survey. Towards the end of the project, the documentation requirement led to the majority of the workload so that fewer new and motivating results could be achieved.

The trend of the surveys is reminiscent of the team development phases according to [18] what serves as a basis for interpretation. The decrease in self-assessment after *forming* in the course of *storming* with subsequent increase in *norming* and *performing* and adjourning is described as a recurring team process [18].

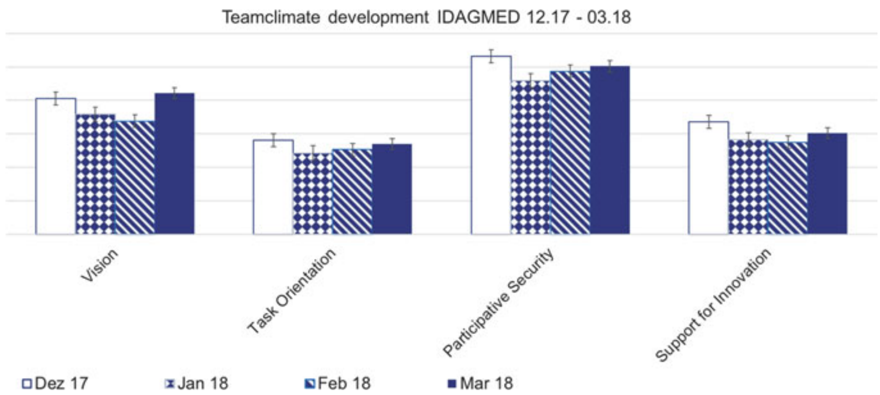


Fig. 69.4 TCI results

The limitations and boundary conditions, some of which only became apparent during the project, demotivated the team for example current requirement changes. By developing own standards in the numerous retrospectives as a solution for these boundary conditions, a constant increase in motivation and self-assessment occurred.

69.6.2 Feedback and Observations

The effects of agile methods on teamwork can best be seen using the feedback log. More than 200 quotes and comments showed that the distribution of tasks for example at the beginning of the project was not clear and an introduction process of scrum had to be controlled by clear rules after the initial euphoria. Formulating and maintaining user stories were a major problem. The adaption to physical product development by relaxing the formal rules helped to solve this problem.

The obligation to maintain secrecy and documentation for medical development processes was considered demanding, but not an obstacle. Rather, the ability to produce complex medical products within one sprint was doubted.

With constant evaluation of the working methods in the retrospectives, the team’s expectations for its own results increased and above all, the need for physical presence during working hours increased. Remote solutions were reduced or discarded in the course of the project. In summary, this leads to the following answer to the research question (Q1).

Agile methods accelerate the team development process at the beginning, but the additional effort due to the new process rules is most profitable after about 3 sprints. Afterwards the well-rehearsed team can benefit from the known scrum standards and developed practices.

69.6.3 Recommendation of Action for the Next Phase

From the prior observations, the following recommendations for future agile development in medical technology were developed.

For the overall set-up of future medicine product development projects, shorter sprints and a division into pre-, iteration—and final phase are recommended. In Fig. 69.5, all of the following points are illustrated.

Research, interviews, and joint workshops on the topic would be urgently needed before the actual development. This would allow consensus to be built on the goals and vision of the project, technical knowledge, boundary conditions of the product, a common picture of the end-user of the product, and primarily an understanding of agile methods. The approaches of Design Thinking according to [19] could be used to align the project goals and vision.

The middle iteration phase should follow the sprint structure of Scrum. Supported by pair programming for efficient teamwork and classic techniques from product development, innovative solutions for partial problems can be systematically developed. For the selection of the documentation and technique level during a sprint, the sprint missions should be used. In order to keep an eye on both technical requirements and user needs, personas according to [20] or so-called products should be used, to evaluate the work results from the preliminary phase.

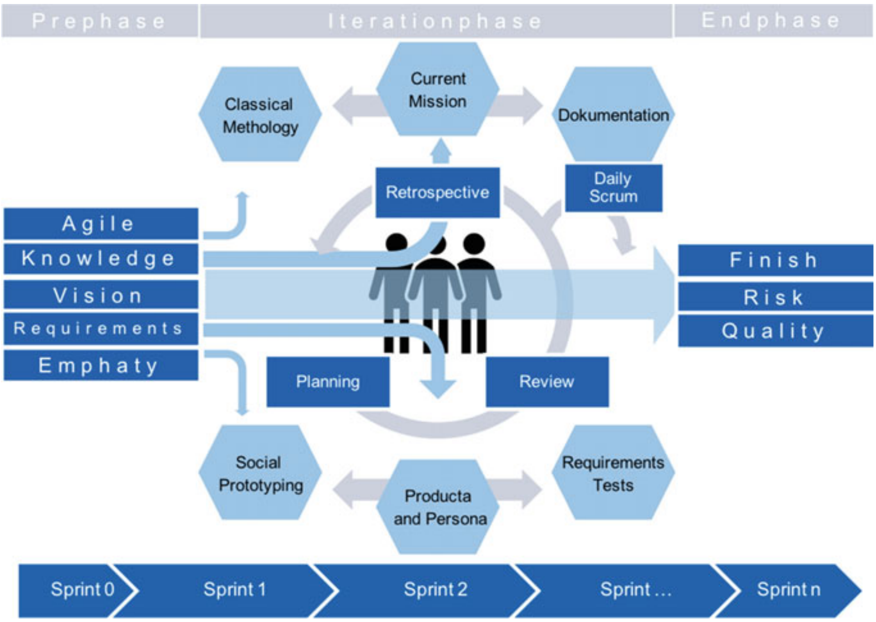


Fig. 69.5 Recommendations of an agile process for physical product development

The final phase served to ensure the fulfilment of the vision and to prepare the final presentation and documentation. Therefore, it would make sense to coordinate this in a final part independently of the regulations and sprints. This would make it possible to adapt the documentation to the requirements of a previously untreated risk and quality management system and thus meet the most important requirements of medical technology product development. The extent of such a final phase depends on the desired degree of maturity of the product but should not exceed one to two sprint lengths. In summary, the answer to the research question (Q2) is then as follows:

The main point to adapt agile methods to the IDAGMED project was through the approval of research results as product increment/results. For a better targeting of the development, a division into three phases is proposed, which consist of orientation, sprint-wise implementation and a final securing-phase. In addition to customer requirements, technical boundary conditions must also be continuously monitored.

69.7 Conclusion and Outlook

The aim of the study was the introduction and adaptation of agile methods to the project for the development of medical technology products.

The project team was involved in the development and optimization of microtiter plates for automated use in cell culture tests. The project results were prototypes printed with additive methods and simulation models of existing microfluidic geometries. They were developed in five four-week sprints and frequently adapted to changing customer requirements. In addition, the project team provided numerous scientific insights into the possibilities and limit of additive manufacturing processes for medical products.

The quantitative self-assessment of the team was measured several times through the survey using the team climate inventory. The general course of this self-assessment followed an U-form.

As recommendations for the second project phase, a three-part project phase was proposed. The large amounts of information and work content and the need for the team to get to know each other speak for a preliminary phase. During the subsequent iteration phase, new artefacts such as persona and product increments as output from the pre-phase could be regularly tested for their fulfilment in order to check both, the needs of the users and the technical limitations. The goals of the individual sprints should be set out in missions that serve the selection of suitable product development methods and the scope of the documentation in sprint planning. At the end of the project, a final phase should be completed, in which the final adaption of the product can be conducted and, if necessary, risk and quality management can be taken more into account. Recommendations were also drawn for the content, scope, and conduct of meetings in order to promote for efficiency. In addition to the evaluation of the recommendations in Part II of the IDAGMED project, further points project: for the quantitative analysis of the effects of agile methods on teamwork, measurements and surveys must be scaled in duration and sample size. From a larger basis of data, patterns could ultimately be derived that provide information about the effects of agile methods independently of other influences.

The securing phase, which is most relevant for medical technology requirements, should be further specified and investigated by concrete implementation of risk and quality management in future projects.

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Chapter 70
Eri-Culture: The Drive from Tradition to Innovation

Umme Hani and Amarendra Kumar Das

Abstract Assam, a north-eastern state of India is a land of variety of silkworms. Eri-Culture is an age-old traditional practice of rearing of Eri silkworm. Eri is a kind of silk with thermal quality and hence, the poor and the underprivileged used it to replace the woolen clothes. The tribal folks of Assam mostly practised it. Eri silk was also known as the "Poor Men's Silk" since it was the cheapest and the sturdiest among all the available silks. Today, the tradition took a drive towards the global market with a different grace. The Eri silk fabrics that are being constructed by the handloom weavers are in huge demand not only in India but also outside the nation. The involvement of the Designers and Industrialists led to a remarkable revolution through intervention and commerce. The discussion laid here is about the power of Design and Innovation, which could easily turn a Cultural Heritage of Handlooms into a commercial industry. The argument additionally concerns the need of an understanding for those who are performing interventions in the Eri silk sector to focus on certain aspects so that the Tradition and Heritage are not being harmed. The interference of Design professionals into this sector has undeniably helped the weavers' community towards crafting a better livelihood. But sometimes, age-old traditional designs with a touch of contemporary drifts also turned out to be extra rewarding.

70.1 Introduction

Eri-Culture is one of the age-old sericulture and textile practice, which is being accomplished in the north-eastern region of India. This is a traditional activity, which is agro-based, and eco-friendly. This activity was predominated by the poor

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class people of the society [1]. The end product "Silk" was considered as poor man's silk, which was used to replace woollen fabrics during winter for its specific thermal property. It was popular among subordinate income generating communities because of its cost-effectiveness [6].

According to the official statistical report (2005–2006), the count of families that were involved in Eri practice is 1.5 lakhs, which counts up to 70% of the total families involved in sericulture in Assam [2]. The history of Eri-Culture in India is found to have its first reference of documentation in the year 1779. It was found that the Eri was discovered in Assam and hence was called Assam silk. There are two specific silks available in this region namely Eri and Muga. Eri is the sturdiest silk among other available silks in this region and now it is domesticated in the north-eastern regions India.

Eri silk became very popular and its demand began to upsurge rapidly with the phase of time. The export of the silk products started to commence with the involvement of Assam Apex Weavers and Artisans Co-operative Federation Limited (ARTFED). And eventually, every year a lot of Foreign exchange was experienced with its increasing demand [1].

According to a study [2], it was found that Eri silk production output was growing significantly at 5.9% annual exponential rate during 1980–83 to 2002–05. Also, the capacity that it holds in solving the unemployment problems in the rural parts of Assam is very less. The Eri practice comprises of the activities from cultivation of Cocoons to the production of silk (fibre) along with the process of creating handloom fabrics. In Assam, the poor tribal communities like Misings, Kacharis, Bodos, Mikirs, Rabhas, Karbis and Garos mostly practise it [2] and mostly the women are involved in this activity. A large number of families came out of poverty line because of Eri- rearing and Weaving activity. An assumption was made that if the practice of overall Eri silk production is accomplished in a more innovative and creative manner, this activity can create an ample scope of sustainable employment and generates income for a wider section of rural population of Assam, India [3].

The main aim of this research is to find out how the overall development took place in the Eri sector with the involvement of proper management, design intervention and innovations. It is tried to understand the change that has taken place in this sector from the beginning till today along with future need for the development of this particular sector.

70.2 Literature Review

70.2.1 History and Evolution of Eri-Culture

Till now proper history and origin of Eri silk could not be traced. Eri silk is also known as "Errandi" or "Endi" silk. The word **Eri** came from the word **Era, which** is an Assamese term and it means Castor, as it is the habitat of Eri silkworm. This particular silk is the purest of all. It comes from a silkworm named Samia Cynthia Racini [6]. It is also considered to be very cultured and textured silk.

Eri is mostly short fibrous and not filament silk and hence, it requires more preservation and care. It is textured because of its short fibre, and it is comparatively less durable than other filament silk. Eri is one of the softest and purest forms of silk. Around 60% of Eri produced in India is from the state of Assam and that is why, it gives Assam, the name of Eri silk state.

Geographically, Assam is situated in the north-eastern region of India, and it provides a climate that supports the cultivation of the various host plants of different kind of silks like Muga, Eri and Mulberry. These silks are commonly known as Assam silk worldwide. Just like other sericulture activities, the Eri-Culture is also broadly divided into two parts. One includes the cultivation process and the other one is Eri textile industry. The cultivation process involves the sowing of seeds, cultivation of the host plant and maintenance of the host plant. It is then followed by the plucking of leaves from the planted trees and sometimes from wildly grown trees. The leaves are often collected from Eri Concentration Centres (ECC) and after that, feeding and rearing of pupae is done up to cocoon stage (Figs. 70.1 and 70.2).

Performance of castor genotype is a vital criterion for healthier progress and development of Eri silkworm for advanced efficiency in terms of cocoon and egg production. Growth, development and reproduction of the insect are strongly reliant on the quality and quantity of foodstuff consumed by it [4].

The Eri-rearing practice is running as a cottage industry, and it is considered as a part time occupation for livelihood and earning for the rearers. Sometimes, non-availability of sufficient quality leaves becomes limitation for large-scale

Fig. 70.1 Eri silkworm

Fig. 70.2 Eri cocoon

commercialization. Considering the above factor, Dr. Jogesh Deori came out with a solution of Tapioca (Manihot esculenta) as an alternative food plant for the silk-worm and it is widely available [8]. The cultivation process and the scientific research in this area indicate the importance of this particular silk in the market. The demand of this material in the global market has led to the advancement in the scientific revision towards the development and growth of the silk worm.

The other category, the Eri-textile industry is the major subject in the current context. It includes the post process of producing fibres from the cocoon, which is followed by the spinning process. Spinning is again of two types, one is traditional hand spinning method and the other one is machine-spinning method.

Traditional method is hand spinning, which is still followed in certain places depending on the requirements. Hand spinning technique results in uneven yarns resulting in textured fabrics after weaving. Semi mechanized spinning machines are also in use along with hand spinning techniques which results in similar texture but consumes much lesser time than traditional method (Fig. 70.3).

Nowadays with the technological advancement the proper large-scale machine-spinning mill has been also introduced in industrial level. Field study was conducted to visit Fabric plus industries limited and Indi Luo in Assam to understand the yarn quality of those spinning mills. The yarn generated from Eri silk fibre in those mills, results to be more lustrous, fine and smooth.

Fig. 70.3 Hand spinning process and semi mechanized spinning process

70.2.2 *Past, Present and Future of Eri Industry in the Context of Handlooms*

70.2.2.1 The Past

- During the pre-independence era, a miniature effort was created to develop the handloom sector. Handloom weavers were potholed against modern textile mills. They writhed to survive against antagonism from industrial products, exploitation by middlemen and the vicious circle of liabilities. The production was generally of poor quality because of substandard raw materials and bad organization.
- The time of independence witnessed about three million handlooms in the nation. Because of inadequate market-knowledge, lack of promotion and inconsistency in the quality of products, weavers were unable to get equitable price for their produces.
- In the 1960s, substantial state funding began with innovation and technical enhancements. New marketplaces were generated and road connections were upgraded [7].
- For more than 40 years now, the handloom industry has been receiving assistance through a comprehensive variety of policy measures at the state as well as the central government level.

70.2.2.2 Recent Trends

- In the present-day scenario, the handloom culture has gone up to one more level where proper export is observed with an increasing demand of Eri silk in the countries like USA, UK, France, Germany, Netherlands, Japan, Belgium, Australia is observed [6].
- Technological advancement and emerging of proper handloom industry have created a boom in this sector. Proper spinning industry is available to provide efficient result by providing even and fine quality yarns.
- Interventions of the Designers have also influenced the Eri silk industry and again a local level competition has begun.
- Government funding towards enhancement of this particular craft tradition is providing great support in the sustainability of Eri silk.
- A lot of research has been done and is still going on considering the improvement in the production of Eri silk.

70.2.2.3 The Future

- The Eri-Culture in terms of Handlooms demonstrates absolute collaboration of craftsmanship and tradition with the world's leading team of highly skilled textile workers, artisans, the involvement of international designers and the technology.
- The Indian handloom industry is fundamentally scattered and each pocket of the country has developed as a specialized cluster with a certain distinction of its own like Eri as one of the example of northeast India.
- A very prosperous tomorrow can be visualized for this rural practice of India, which can be counted among the most precious assets of this country.

70.3 Objectives

The study intends to understand how Eri-Culture, an age-old traditional activity took a drive towards industrial globalization. Hence, the objectives stated are as follows:

- To study the current market, need for innovation and the role of government and non-governmental organizations along with firm owners.
- To study designers intension or goal while performing any design activity or interventions through observation and interviews.

- To study the contemporary designs involved in the practice and analyse how it is affecting the culture and heritage of handloom industry.
- To understand the actual benefit of the artisans in the entire process.

70.4 Methodology

This research paper is based on qualitative method which includes field visits along with a series of interviews, both individual and focus group of owners who manufactures and supplies Eri products, few designers and director of central silk board.

To understand the government and non-governmental interventions and their outcomes, a qualitative analysis was also done to understand the benefit through proper questionnaire and survey to analyse the satisfaction level of the artisans who are involved in the handloom weaving activity.

The literature is based on the secondary data composed from different research papers, journals, and government reports to understand the past and current scenario of Eri silk industry.

70.5 Intervention of Government and NGOs

The Central Silk Board (CSB) has been implementing a Scheme namely "Integrated Scheme for Development of Silk Industry" for development of sericulture in the country, which focuses and emphasizes on improving production, quality and productivity of domestic silk thereby reducing the country's dependence on imported silk.

Government plays a very important role in the overall promotion and growth of the handloom sector. There are various schemes implemented by the government for the growth and development of the handloom industry of India. The non-governmental organizations (NGOs) help in recognizing certain areas where the practice of weaving is very common and helps the artisans in building clusters. The clusters are being identified and provided with Common Facility Centres in order to carry out the weaving activity in a proper atmosphere with various sustenance provided by the government. Provided the schemes are executed in a suitable approach, a positive impression has been perceived. The government also supports in marketing and export of various products through organizing different types of trade fairs and exhibitions every year.

An impact assessment study was conducted in order to comprehend the benefits of the weavers from government interventions in two different Eri practising regions, one in Mukalmua (situated in the Nalbari District of Assam) and the other one in Kokrajhar, Assam. The CFC's were observed properly and the artisans were interviewed.

Table 70.1 Mean value of 7-point Likert scale showing the satisfaction level of the weavers

	Before joining CFC	After joining CFC
Satisfaction from income	2.4	4.6
Access to medical facility	1.2	3.8
Education for their kids	3	5
Access to raw material	4	8
Volume of production	2.6	4.2
Access to market	2	6
Sales and profit	2	5
Variations in design	3.2	6.5
Overall working environment	3	5.3

To assess the satisfaction level of the weavers, a questionnaire was designed to know the satisfaction level of the artisans before joining the CFC and after joining the CFC, where we could take around 90 samples in consideration. Continuing with that, few questions were formulated with Likert scale, which comprises rating of 1–7 where 1 equals to highly dissatisfied and 7 equals to highly satisfied. The result of which is shown in Table 70.1.

After analyzing the overall result of the filled questionnaire, it is found that the implementation of the CFC's has actually shown some improvement in the overall lifestyle of the Eri weavers in most of the cases.

Most of the weavers were also benefited through the fairs and exhibition organized by the tourism sector and other organizations like the HEPC (Handloom Export Promotion Council), NHDC (National Handloom Development Corporation).

70.6 Intervention of the Designers

The designers play a very significant protagonist in shaping the entire system. When it comes to the development of fabric, the collaboration of the designers with the artisans generates very effective results in the process of product development. Typically, the Eri silk was considered as the poor man's silk and it used to replace the woolen fabric during the winters. Eri-Culture was purely a traditional home-bound occupation, which was accomplished just to fulfil the domestic prerequisites. With the phase of time, this particular silk became very popular all over the world. Various silk industries came in existence and gave this tradition a new shape and started developing diversified and contemporary products, which are being exported outside the nation.

Few designers from the region were interviewed to identify the design process they follow while executing their profession in this field and it was perceived that, most of them designs according to the buyers requirement. The colours and the patterns, which are extensively being used, lacked the traditional motifs and patterns. They think that the use of those elements might obstruct the demand of the product and might not target the large group of users.

Few designers do use the traditional elements (motifs and patterns) in their products and are able to capture the domestic markets and also the high-end clients. One of the designers, Anurdadha Pegu, mentioned in her interview that in order to maintain the overall traditional aspect of Assamese handloom tradition in the context of culture, she only uses traditional methods of weaving and creates patterns in traditional looms only and try to keep the cultural heritage alive. Design can support susceptible livelihoods in craft, rather than evaluating what was designed [9]. Designer is a mediator between technical and cultural world, who offers a new way of understanding mixed, sociotechnical skills and it emerges as design culture [9].

In investigating, how design and handicraft production can be combined, we should start with an analytical division between craftspeople (as designers), and designers (servicing craftspeople) say Chatterjee. He also adds that the Designers have established the probability of design as a confirmed approach for poverty mitigation of the craftsmen, artisans and weavers in India [10].

70.7 Observations

The overall understanding reflects that innovation and interventions have undoubtedly had a positive impact in the handloom sector but still some improvement is required. There is a future scope of further design intervention in this particular sector. Even though the weavers seemed to be quite satisfied with the working environment but still further improvement is suggested.

The centres are quite spacious but during summer season it becomes really hot because of the ventilation. Same problem was observed in both the CFC's and a proper design solution can be proposed in the context of workplace design for better efficiency. More tools can be designed in order to reduce workloads.

The weavers were also quite satisfied with the engagement of the Textile Designers and the Master weavers but the traditional and cultural aspects were missing. Assam is a land of various tribes as already mentioned above and each and every tribe have their unique designs and motifs. The Assamese identity was not found in most of the products, which needs to be taken care of. Also, a contradiction was raised [5] that there is a requirement of proper guidelines for performing intervention so that the culture or the heritage is not being maltreated. These contradictions can be taken forward as a study. Here, the design practitioners can also play an important role towards creating a new platform for preserving the traditional motifs and design and also creating variations of those designs. Those designs can be digitized in a ready to use format, so that the weavers can get easy access to them build a better market for themselves. The clients can also take this forward as a customization approach.

70.8 Need Identification

The overall study determines certain necessities, which needs to be incorporated in the Eri silk sector, not only to improve the survival of the weavers but also to give them a proper identity. The partnership of Eri silk threads and the Handloom culture of Assam is a very important asset of this country, which not only creates employment but also attracts tourists.

Eri-Culture is a tradition and a part of rich cultural heritage of this area. Considering these factors, an appropriate research-based design solution is needed. Other areas like publicity, marketing, visual merchandise and branding are also very important requirements.

To fulfil the above need, an initiative is taken to provide solutions for the designers, which can help them in creating demand for traditional motifs and patterns. A designers guidebook will come up which can guide the young designers and make them aware of the cultural heritage and tradition of textiles of this region and also help them is promoting the traditional designs and motifs. As already mentioned in Sect. 80.7, digitization is the next step of this research where it will be tried to design a proper system, where the weavers can directly access the traditional as well the modified designs to the local Handloom office and design fabrics for their clients.

70.9 Conclusion

The Eri-Culture of Assam is one of the age-old cultural activities and it has seen tremendous change throughout the history. From fulfilling, the warm requirements of the poor segment of the society to the supply of luxurious drape of Eri Fabrics, this culture is nurtured in a very progressive fashion. The involvement of proper intervention can create very positive impact in the society.

The future of Eri silk industry can be very strong not only in terms of revenue generating but also in creating a historical society, if the identified need is practised appropriately. The weavers and artisans need proper education towards management and can creativity. A lot of work is yet to be done in terms of marketing, organizing and managing the overall business in order to come up with a successful Eri-silk Industry in the context of Handlooms.

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Chapter 71
A New Linguistic System for Communicating Design

Sabu Francis

Abstract This paper proposes an accurate linguistic representation system for architecture and other types of designs. Historically, architecture has been represented using drawings. Drawings only have poches that represent only built matter and not spaces. Even alternate systems concentrate on built matter and not spaces. Emergent knowledge from design processes using such systems can have corruptions. Conventional systems could, at best, help at the stage where the design is finalized. Using them in earlier stages can be corruptive. Though this paper refers to the architecture of buildings, it is possible to use this linguistic system for all kinds of designs. It has been in use for over two decades.

71.1 Introduction

The paper asks this question: *how do we communicate knowledge in the vast subject of architecture?* It also provides an answer: a new linguistic system for all of the architecture. Though the author used this system in his own practice starting from 1989, this system is still termed as "*new*" because it is not widely used.

71.2 Acronyms and Definitions

AEP—architectural evolution process—is the entire life cycle of the process of creating architecture, right from hazy stages of inception all the way to the use of the design. Some parts of the process may be iterative.

SL—specialist language—is specifically used to communicate for a specialist field. An SL is not the same as the natural human languages. However, there are lessons from the broad field of linguistics which apply equally well to SL too.

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LS—Linguistic system. It is a broader term than SL and can apply to SL in different fields.

71.3 Assumptions

- The reader is expected to be familiar with linguistic theories.
- A clear SL is a critical starting point in shaping knowledge in the subject of architecture.
- The asynchronous form of the use of language is critical to the shaping of knowledge rather than the communication of knowledge via humans interpreting the subject synchronously. Simply put: *written word* is more critical than *spoken word*.[1]
- This work does not base on some assumption of quality of work in the architecture. This paper addresses the "how" and not the "what". There is no specific a priori quality statement emerging from the SL to bias the design.
- The term "communication" (and its variations in English grammar) used in this paper expressly refers to a dynamic process of interpretation by collaborators. This excludes purely introspective dialogs (such as soliloquies). Unless otherwise specified, advocacy of some point or the other is seen in such communication.
- The word "representation" means any communication system (not just SL) that is used to communicate the design process—e.g. a physical model.

71.4 Scope

This paper does not develop new knowledge in the subject of architecture. This explains only the usable linguistic system. Due to space limitations, only a summary of the extensive proposal is given. This system is already in use by the author for over two decades, with plenty of constructed designs out there in the world.

71.5 Purpose

This paper attempts to convince the reader of the following points:

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[1]This is the position taken by Jacques Derrida, philosopher and linguist. Not everyone agrees with this position.

(a) A formal linguistic system (LS) is needed to represent architecture at any given stage of its creation, i.e. right through its AEP, and a specialist language (SL) is critically needed.
(b) A more ambitious goal would be to use this linguistic system for all of the human-made objects. Hence, knowledge of all objects from a city to a bottle ought to be communicated accurately with this SL.
(c) It is often critical to get relevant answers for many different phenomena and issues in architecture at a very short notice. Right across all the stages of the AEP. Hence, a third and yet important use of this document would be in computerized automated or semi-automated processes. The formal structure of the SL should assist in such processes, looking at architecture in a neutral manner with no biases whatsoever.

71.6 The Problem

Let us examine any negative effect once a building appears in the real world.

Be it energy loss, ill-health in the occupants of a building, issues arising due to carbon footprint, unsustainable building practices, etc. Let us systematically peel away right through a multi-layered causal chain and reach the initial abstract causes.

At the end of any such causal chains, one finds that incorrect communication during the initial stages of inception as well as across the entire AEP played a crucial role in producing such eventual end effects (butterfly effect). It is imperative that all stakeholders agree on a clear SL for the entire design process.

71.7 The Logical Flow

The author examines some accepted conclusions from an overview of structural linguistics, lessons from the post-structural work of Jacques Derrida [2] and lessons from the subject of epistemology. Finally, the author proposes the new SL for architecture and then shows some examples of its usage and applicability.

71.7.1 Lessons from Structural Linguistics

Saussure gave us the concept of “parole” (French: *speaking*) and “langue” (French: *language*). The former is the idiosyncratic way by which the spoken language is used by individuals. The latter (*langue*) emerges when a collective of people agree upon the formal set of grammar of the language.

Either in the *parole* form of expression or in the *langue* form, one would see a clear understanding of various "*paradigms*": if two different expressions have the same paradigm, then they both have a similar structure. A paradigmatic relationship is one where an individual sign may be replaced by another.

Each *parole* statement would have its own "*syntagm*": pieces of language, taken together in prescribed structural relation, combine to form larger meaningful pieces. Put it plainly, it is the syntax of the language.

Though not specifically clear in the existing literature, the author believes that the process of *parole* turning into *langue* could also be regarded as the "*diachrony*" seen in language.

Usually, *diachrony* is seen in a historical context—where the *langue* itself changes over large periods of time. This author's contention is that this process can be seen in smaller periods of time too, such as when one starts explaining some concept hazily and moves onto clarity.

That means, to obtain clarity, the meaning could start idiosyncratic alright (as "parole") but then it becomes more structured and moves into a commonly accepted *langue*.

The term "*synchrony*" applies to the examination of the expression at any given cross section of the process. The term "*diachrony*" applies to the patterns in the entire longitudinal period of time during which the expression kept changing.

Each point in that transition can be examined cross sectionally in its *synchrony* for the presence of specific *syntagm*. One could keep examining each of the *syntagms* over time and then take notes on how the meaning kept changing.

Each of the points in the transition of the *parole* to the *langue* can be analysed *synchronically*. One can make some inferences based on the *syntagm* for each point in time. Then, such set of *synchronic* meanings leads to the *diachrony* eventually establishing clarity in the langue. A point or set of points is then communicated.

Such an evolution of meaning also essentially captures how one acquires knowledge in specialist subjects too.

This transition can be often seen when an architect designs: the architect starts with sketches and personalized diagramming (*parole*), some of which cannot be understood by anyone other than the architect. Iteratively, the architect clarifies the design till there is consensus between the architect and his/her audience. Unfortunately, this manual process cannot be fully examined in the aforesaid linguistic rigour.

The author posits here that for any specialist language to succeed one needs to examine meaning synchronically at all points in the evolution, so that understanding the *diachrony* is possible. Such a capability is critical. In architecture, the capability to start communication using a parole is also critical.

One important facet of linguistics generally agreed upon by linguists is the facet of "*production*"[2]—whether in *parole* form or in the *langue* form; it is possible for a

[2]Steven Pinker, Professor of psychology at Harvard, explained the concept of "production" in an excellent video https://www.youtube.com/watch?v=Q-B_ONJIEcE.

true language to produce all kinds of meanings: authors can invent any *paradigms*. In fact, this capability to produce any form of expression is a necessary condition for a form of expression to be regarded as a language.

It is this author's position that any SL for architecture should necessarily have such a facet of "*production*"—else it can bias the quality of the architecture being communicated in its AEP.

Among linguists, there is a hotly debated hypothesis called the "*Sapir–Whorf hypothesis*" which puts forward the provocative theory that a person's world view is shaped by the language that is used. This hypothesis is meant for natural languages.

The author posits that this effect can also be seen in specialist languages. For example, modern CAD/BIM tools allow very complex shapes to be designed. It is a hotly debated topic in architecture, where some insist that these shapes may have come into reality only because the software allowed the creation.[3]

The lesson from the "*Sapir–Whorf hypothesis*" is that the SL which gets accepted in architecture should not be biased towards any specific kind of architecture.

71.7.2 Lessons from Post-structural Linguistic Criticism

There are two important lessons from post-structural linguistic theories, as observed by Jacques Derrida

(B-a) The meaning of any word is not absolute, but it is deferred to a definition which itself has a set of words and those in turn may need further definitions. When seeking meaning for a word, one is pointed to another set of words; and then, recursively one would need to look up some, or all, of those words. This continual state of deferring is one of the main characteristics of language that Derrida calls as "*differance*".
A proper language allows for continuous exploration, interpretation and creativity (and therefore "*production*") in the use of language. A lesson here is that if the SL insists on some component with a firm pre-decided definition, then that is surely an unwanted bias. It can even hinder continuous creative production.

(B-b) There is a tendency in language to bias meanings towards one half of a binary pair. For example, Jacque Derrida coined the term "*Logocentrism*" to indicate society's preference on the importance of spoken word over the written one.
In fact, the written word has played a crucial role in shaping society. Even in SL, the clarity of the asynchronous (written) form of a subject has

[3]"Even in experienced hands, parametric programs can produce alarmingly undisciplined results" http://www.architectmagazine.com/design/parametric-design-whats-gotten-lost-amid-the-algorithms_o.

enormously influenced further thoughts in the subject. There are many other such binaries—such as male–female, west–east and so on. And in each such binary set, humans tend to become lopsided, favouring one part of the binary set over the other. All such biases hamper communication.

If there is no check to see the importance of the opposite concept in some linguistic statement, there is a chance that one may corrupt the meaning in the communication.

Interpreting the above two, the author can posit the following:

(B-1) Any SL for architecture must necessarily not state constant meanings for the ingredients inside that SL but allow the meaning to be recursively derived in a similar fashion as seen in regular human languages, i.e. using "*differance*".
(B-2) The SL for architecture should not have pre-defined "plug-and-play" components with pre-decided meanings.
(B-3) Any SL for architecture must necessarily not be biased towards any one side of binary sets that are found in the architecture.

One major bias in a well-recognized binary set found in the architecture is the preference towards built matter over spaces. Architecture becomes useful not just for what is built, but also for what are left as voids. The reader is requested to look up a verse in *Tao Te Ching* that poetically explains this.[4]

Thus, to communicate architecture right through the AEP, the representation system ideally should not focus over only one with the exclusion of the other. This is one of the main bones of contention that this author has with existing representation systems in the architecture. The other one being that conventional systems do not allow for a diachronic examination of the AEP.

71.7.3 Lessons from Epistemology

(C-1) A statement can either be a descriptive claim or a normative claim. Epistemologists generally agree that only normative claims can advance knowledge; they are the ones where the statement takes a quality assertion too.

Descriptive claims simply state their stuff—and this author posits that such a situation can invite unnecessary quality interpretations which could be wrong. One of the strong issues that this author has with existing ways of communicating knowledge in the field of architecture is that they are often mere descriptions.

A floor plan (or any other technical drawing for that matter) is mere descriptions of what is being built. There is no systematic method to conduct

[4]Tao Te Ching Chapter 11 http://www.wussu.com/laotzu/laotzu11.html.

a dialog in a drawing. All those happen post-facto are highly personal interpretations and therefore controversial.

(C-2) A piece of information becomes a piece of knowledge, if it has three attributes: it is a belief that is put forth, it claims to be a truth, and it justifies that indeed it is a truth.

(C-3) Discussing belief and truth is beyond the scope of this paper. Also, there are exceptions to the theory of knowledge—often called Gettier [1] cases. This has relevance to the SL proposed here. But they are all specialist discussions left for later. To justify something to be true, there are cases where one can use neither deductive logic nor inductive logic. This is especially so during the early stages of design.
Understanding and advancing the knowledge by staking a justifiable normative claim are hard in such cases. Hence, one needs to propose a set of alternatives with the same *paradigms* and then choose the best from within that set. This approach is called "*abductive logic*".
For example, let us say the architect needs to decide on the correct arrangement of rooms for a house. The architect needs to choose one from a set of alternatives expressing the same *paradigm*. See Fig. 71.2.

71.8 The Proposal

The author posits that it is possible to express any piece of architecture or human-made object by delineating the geometrical boundaries of both spaces and solids and establishing a topological relation between them.

There are three classes which demarcate spatial boundaries and two abstract classes that demarcate solid boundaries. All these definitions are ontological in nature; i.e. it is based on a socially accepted understanding of the "being" of the thing. Yet, these "beings" are abstract, with no analogy to reality. See Table 71.1.

To obtain *left-overs*, one would do the following mathematical Boolean operation on the geometry: *left-over* = *Envelope* − $\sum$*Atoms in the envelope* − $\sum$*Connectors in the envelope*.

This equation is not a metaphor. The Boolean math yields more detailed geometry and logic of the concerned architectural element. Hence, any architectural element, large or small, can be expressed as a collection of the aforesaid five classes, with the sixth one (left-over) appearing as an emergent data, with further fractal references.

This is explained in Fig. 71.1.

Table 71.1 SL describes "alphabets" for both spaces and solid matter

Spatial elements	Solid elements (volumes contain matter)
1. *atom* = the smallest space that the architect defines as a whole, recognizable entity in that element 2. *connector* = the boundary of that spatial element that serves the purpose of connecting one or more other spatial elements; i.e. it will necessarily have coincident faces 3. *envelope* = the boundary of that spatial element that serves as the silhouette of other spatial elements	1. *artefact* = the boundary of that solid element which is considered as something made of built matter socially 2. *linked-node* = a set of artefacts that are interrelated in some meaningful manner 3. There is a sixth abstract class that naturally emerges from the Boolean operation between the aforesaid spatial classes. This class is termed a "*left-over*"—it is a special kind of solid matter

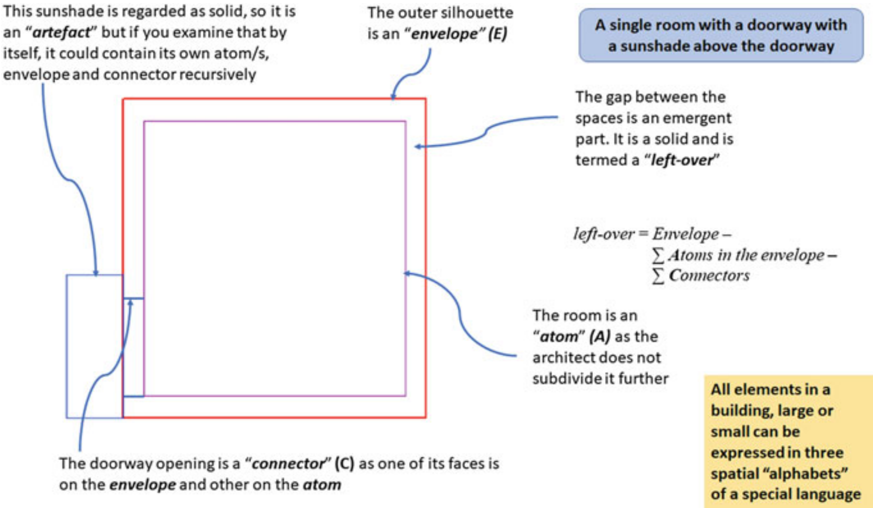

Fig. 71.1 All of the architecture expressed using three abstract spatial alphabets

71.9 Checking the Lessons

The author wrote a software which did this kind of modelling, and all the projects done by the author in his practice used this system. The software was also used in a couple of research projects for calculating heat loads of buildings and other climate considerations.

This SL does meet many, if not all, the requirements. This software works because the models made using this system have the capability to "explain itself" using the previously mentioned classes. Same paradigms can be explained in different arrangements. See Fig. 71.2. The SL is quite clear and non-controversial.

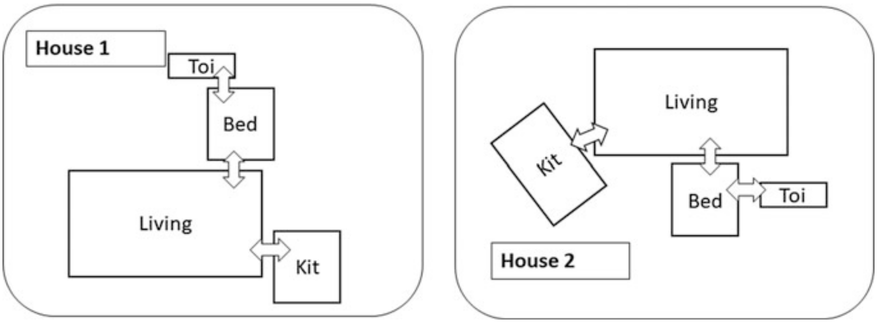

Fig. 71.2 Same paradigm but different arrangements in two houses

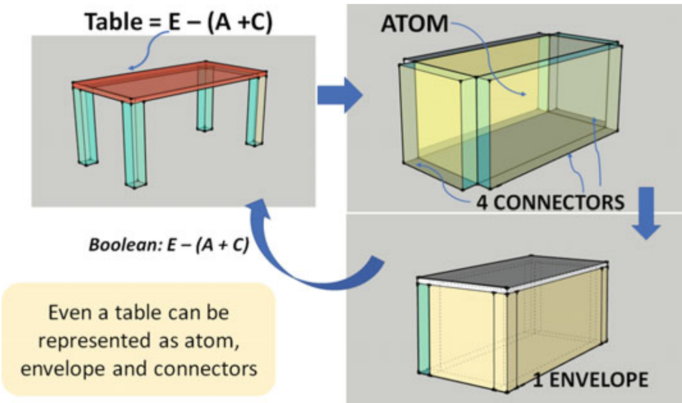

Fig. 71.3 Recursive, fractal nature of this specialist language

This system has the characteristics of a fractal. In the above example of a simple room, let us place a table. That is, as per the above ontological definition, is an artefact as it is socially defined as a physical object; i.e. it is a built matter of some sorts. It not only allows for *production* (as defined by linguists) but allows for dynamically derived meanings ("differance").

If we examine that table just by itself (i.e. one descends into the next scale of the fractal), you will find that the table itself is a collection of atoms and connectors within an outside envelope of the table. This is shown in Fig. 71.3.

The "*left-over*" now represents the wood that was used in the table. Theoretically, at least one can go recursively into the table and find the aforesaid collection of atoms, connectors, envelope, etc., once again in a self-similar fashion at all scales.

The above method allows for an extremely efficient method of representing any built object. It allows highly accurate descriptive claims on the architecture. To put it simply, one can easily create a highly accurate model of the architecture with this

SL, and one can even have hazy, diagrammatic representations too during the early stages of design—as explained later.

Since detailed parts can further be explained using the same concepts, one now has a very simple yet accurate method to describe even most complex of man-made structures, from cities to buildings to bottles.

This SL respects the "binary" (of both built matter and spaces) that is found inside man-made objects while giving credence to both. As all the descriptions are not analogies of the real world (such as, the aforesaid "*atoms*" do not exist in the real world. It is just an ontological classification), it is now possible for collaborators to discuss without getting entangled with the meanings of the alphabets.

This system also handles the movement of communication from *parole* to *langue*. This SL is not a rigid one. For example, if one were to place an "atom" in a design, there is no demand that it necessarily had to be placed inside an "envelope" too—for the architect may not have yet decided on where the design is headed towards.

Since this is a loosely coupled system, it is possible for the architect to establish his/her own *syntagm*—usually due to cultural reasons where the project is situated. This is how various kinds of *syntagma* emerged in human languages too.

For example, the arrangement of subject, verb, object in a sentence varies from one human language to other, culturally. This is very different from existing CAD and BIM systems. In conventional BIM software, it is impossible to place an opening (a "*connector*") all by itself. Instead, an opening always had to be placed within some built matter (usually a wall).

That approach (by conventional systems) is highly prescriptive and biased and does not respect the way an architect could move from the hazy parole stage to the langue stage in the design communication. Nor does it respect all kinds of *syntagms* that maybe needed culturally.

Conventional systems do not allow starting in any idiosyncratic fashion—they expect that you would work in what they believe to be a logical fashion. Of course, an architect can employ fake walls and then insert openings into that wall. But that approach is a "Maslow's hammer" arm-twisting of the system for the *parole* requirements.

Nevertheless, in the SL proposed here, as the AEP progresses, towards the end of the designing process, the design would surely fit in logically with all the previously mentioned classes of spaces and solids falling into place correctly. Hence, it does result in highly accurate and accurate descriptions of the eventual design too.

If the entire process of moving from the *parole* to the *langue* is captured, it would be possible for any future critic to know how the eventual architecture got designed from right from inception onwards.

It is possible to use the system as an underlying base on which the collaborators can further add properties and notes, to make quality statements of the ongoing design. One of the ways by which knowledge can be advanced is when one makes normative claims instead of descriptive claims.

To put it simply, the collaborators can "stick their neck out" and claim the quality they believe they can achieve in each aspect of the design, at each stage of the AEP. Furthermore, they can make such quality statements emphatically for any future reader of the representation. The quality of debate around the design then improves considerably.

71.10 Other Systems

None of the alternate systems that the author is familiar with fits the criteria to be a *language*, as explained earlier. They are all some sort of design representation, but none can become a proper *language* as defined by linguists.

Firstly, let us examine the status quo: architectural drawings as a representation system. For drawings are currently widespread. Architectural drawings are, crudely speaking, *pictograms*—a very primitive form of writing. Coincidentally, some pictograms from ancient times even used visual analogies of architectural elements/parts.

Humanity moved away from pictograms containing visual analogies of the world around and instead adopted abstract alphabets for the written human languages. There are no controversies in pure abstract shapes. Each shape of an alphabet does not "mean" anything. Each is abstract and is recognized by its *differance* from the shape of other alphabets. But this did not happen in case of architectural drawings—architects and designer still use *analogies* of the real thing out there.

Furthermore, there is a central issue in such representations of architecture—which is referred to as the "figure–ground" problem. In any representation, the subject matter (*figure*) should stand out and be recognized separately from the backdrop (*the ground*). Technical drawings have this issue of confusing the spaces in architecture with the actual background of the paper itself.

This is the reason it is oft stated that a technical drawing can only contain poche[5]—a French term that indicates the dark marks left on the paper for built matter. This lopsided way of placing importance to only one part of a binary (in this case between built matter and voids) was highlighted by Derrida (*explained earlier*).

Hence, conventional practice of using drawings was discarded by this author as possible LS for architecture. Drawings do have a place in this subject—not as a language system but as a way to store descriptions of the final built forms in the design. Epistemologists could say that is quite a good *descriptive claim* of what is to be built. But it cannot handle the communication during the *process of design.*

It is important for a LS to be able to (theoretically at least) have the possibility to explain any architecture and any form an AEP may take. As explained earlier,

[5]https://mgerwing.wordpress.com/2010/12/21/poche-architects-glossary/.

architects necessarily should be given the freedom to express his/her thoughts from a "*parole*" (idiosyncratic) state to a "*langue*". Many authors also assume that a representation system in architecture is, or ought to be, other forms of analogies to the architecture we empirically observe and use [3].

Systems using virtual reality and augmented reality are in this category. The author strongly believes this is intrinsically flawed as one would bring in real-world cultural biases into the model too. It also ignores the *parole* nature of communication in the beginning of design. An earlier paper from this author argued the case for creating models that are distinctly away from reality [4].

Another paper from the author showed the fractal nature of architecture, which would handle the "*big data*" which is endemic to this domain [5]. Analogies are not fractal—they tend to bring in the enormity of the data from the real world directly into the analogy too. Therefore, they are unsuitable as representation of architecture.

The author does not accept generative systems such as shape grammars and genetic algorithms, as linguistic representations. They allow the overall development of some kinds of designs provided the collaborators accept the analogous premises of the working of such algorithms.

Secondly, they are prescriptive systems that do not capture the dynamic nature of the process for any detailed analysis. In such systems, the subjective nature of communication when proceeding diachronically from parole to langue cannot be fully done. They may allow a progress from the hazy to the sharp, but they are driven by a pre-decided, limited subset of design considerations going along a pre-decided path. There are a priori quality biases that are thrust upon to the architect [6].

Such approaches in designing remind the author of poetry writing algorithms by some AI researchers [7].

Many of the aforesaid alternative ways of representing architecture bias the designer towards rigid pre-decided definitions—they do not allow for the richness of "*differance*" as pointed out by Derrida. For example, many CAD/BIM programs have insertable "blocks" where the meanings are foregone conclusions.

This SL proposed here is markedly different from other proposals for a representation system in the architecture which are quite lopsided towards geometry and often concentrate on the efficiency in the representation of the geometry in the empirically existing building. This is not to state that geometry is not important. It is a critical part of any representation system. But the other points mentioned here are also critical.

71.11 Conclusion

The author attempted to describe a specialist language, a linguistic system, that respects communication in the entire evolution of an architectural design—from inception all the way to design and even usage. It aids asynchronous communication of the design process between creators and critics at every stage. In practice, this system has proved to be quite useful to extract meaningful information quite objectively, in a fair number of projects of different typologies, over many years.

71.12 Limitations

This system can lead to a large change in the way pieces of data exist in architectural knowledge currently. To predict that all such data can have equally well-defined definitions using this linguistic system would be highly difficult.

The author "self-injected" this system into his practice for more than 20 years. It consistently allowed the use of abductive logic, and all works can be clearly criticized for the entire AEP. Though the core mathematics and topological claims can be proved deductively, many other aspects can often be only tested inductively, and the latter may not appeal to some currently. In short, this SL needs widespread and systematic testing.

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Chapter 72
Identification of Optimised Open Platform Architecture Products for Design for Mass Individualisation

Ravi K. Sikhwal and Peter R. N. Childs

Abstract Mass Individualisation is a new product design paradigm that comprises an open-hardware platform and multiple independent modules for end-user's selection that are integrated with the platform. Open platform architecture products (OPAP) are the key enablers for this paradigm. Based on explorative literature analysis, with practical insights from an industrial questionnaire survey, an Innovation toolkit for the end-user has been developed. This provides a means for selecting an optimal OPAP. The design of the Innovation toolkit has been approached in four different steps: modelling of OPAP Products; modelling of evaluation measures and evaluation indices with end-user preferences; identification of the optimal module options for every configuration and Configuration optimisation. Two case studies have been presented to demonstrate the effectiveness and to illustrate that the Innovation toolkit can readily be applied to these types of product development to obtain highly individualised and optimised OPAP.

72.1 Introduction

Industrial product design has changed significantly over time, inspired either by market conditions or the consumers' desire for the product offering. With the industrial revolution, the idea of individually crafted designs was replaced by product design for mass production, followed subsequently by product design for mass customisation. Mass customisation aims at customisation of products and services for customers at a mass production price and efficiency [3]. Traditionally, most products are designed by professionals working for the underlying firms in design teams [4]. However, a significant shift has been observed over time, with

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technological advancement. Innovation technologies (IvT) [5] have facilitated new strategies for product design and development. New technologies have democratised the tools for both invention and production [6]. Anyone with an idea can use advanced and accessible technologies and turn it into a product. Some users are able and motivated enough to share their innovative ideas with firms. Ninan and Siddique [7] proposed configuration tools to optimise and assess the feasibility of customer choices.

The growing saturation of markets and continuously increasing aspiration levels of customers are the primary drivers for the development of customer-individualised products [8]. These products draw on a new set of strategic decisions related to how value is created and captured, and how the relationship with conventional business partners such as suppliers are redefined [9]. These changes in user aspirations and inclination towards more individualised product offering are the basis for a relatively new product design paradigm, known as product design for Mass Individualisation (MI). Explorative literature analysis and practical insights from an industrial questionnaire survey, conducted among consumer product companies, shows that end products in MI are highly individualised and technologically advanced [10].

72.1.1 Product Design for Mass Individualisation (MI)

Product design for MI is based on open platform architecture products (OPAP) that comprises of an open-hardware platform and multiple independent modules. The open-hardware platform is integrated with different modules as per end-user's needs, using the interactive design program. This paradigm is named 'Mass Individualisation' as products are mass produced, but each one is tailored to the needs of the individual buyer [11].

In the framework developed, it is envisaged that large manufacturers will provide the platform of the product along with interfaces for adding modules. These interfaces/modules can be satisfied by different module options. Smaller companies/third-party module vendors will invent and produce module options. Different module options will have different parameters to fulfil the requirements. Thus, the basis of competition shifts from discrete products to modules and product systems consisting of interfaced modules on the product platform.

The variability that MI creates in traditional product design, end-user needs, regulations from different authorities and standards can be challenging. Given the benefits MI provides to all the actors, these challenges are worth addressing. As earlier work [10] suggests, MI could be beneficial in a range of markets, but consumer electronics and furniture markets are well-known sectors that can benefit readily from the end-users' perspective. MI with OPAP can be implemented in various products such as smartphones, smartwatches and individualised furniture.

Although MI has been considered a promising industrial product design paradigm to meet the increased aspiration level of today's customers, it also faces many challenges due to multi-dimensional variations of end products. To model these variations and capture innovation from different actors, a systematic approach and tools are required. Different constraints from so many actors have to be taken into account while solving these models. Xie, Henderson [12] developed modelling for engineering product configuration problems and solved them by constraints' satisfaction. Once the modelling of these individualised products is done, the next step is to identify the optimal configuration with optimal module options. Hong, Hu [13] used genetic programming to identify the optimal product configuration and its parameters for one-of-a-kind production. In this paper, an Innovation toolkit is presented to identify the optimised OPAP for product design for MI.

72.2 Open Platform Architecture Products (OPAP)

Open platform architecture products (OPAP) are the key enablers for product design for MI. OPAP are based on an open-hardware platform with many interfaces for module integration. Figure 72.1 illustrates a typical schematic representation of an OPAP skeleton with interfaces, specific and unknown module options.

Specific module options are the modules selected at the time of first use of the product, where unknown module options demonstrate adaptability or modules added in future as per users' change in requirement. In this work, only specific module options are the primary focus for the development of the Innovation toolkit.

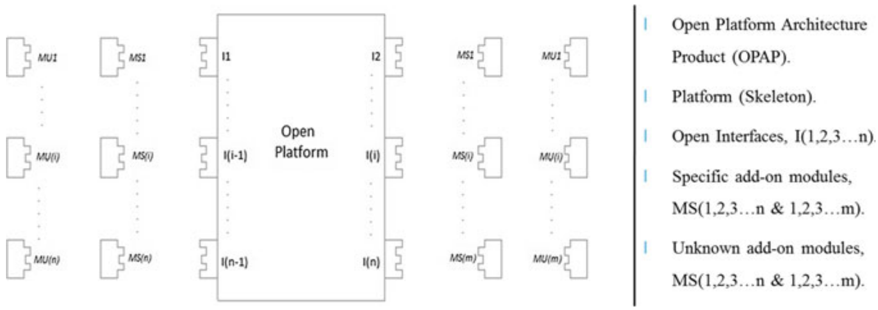

Fig. 72.1 Schematic representation of an OPAP with platform, interfaces and module options

72.2.1 Innovation Toolkit for OPAP

A networked Innovation toolkit describes a design environment which enables actors to formulate their requirements iteratively and transfer these into a producible solution by an iterative process with continuous live-networked support from other actors in the OPAP ecosystem. The function of one module or module system can be optimised with other related modules or module systems with this Innovation toolkit. A multi-level optimisation model is developed for this Innovation toolkit to identify the best design configuration with optimal module options which satisfies all the requirements of the end-user. Figure 72.2 depicts the framework for the Innovation toolkit including roles of different actors and optimisation model.

The design of the optimisation model for the Innovation toolkit has been approached in four different steps: modelling of OPAP; modelling of evaluation measures and evaluation indices with end-user preferences, Identification of the optimal module options for every configuration and configuration optimisation.

The following assumptions are used for the development of the model:

- The end-user acts as a lead to decide on the platform.
- Adaptability and cost of the all feasible configurations with different module options are comparable.

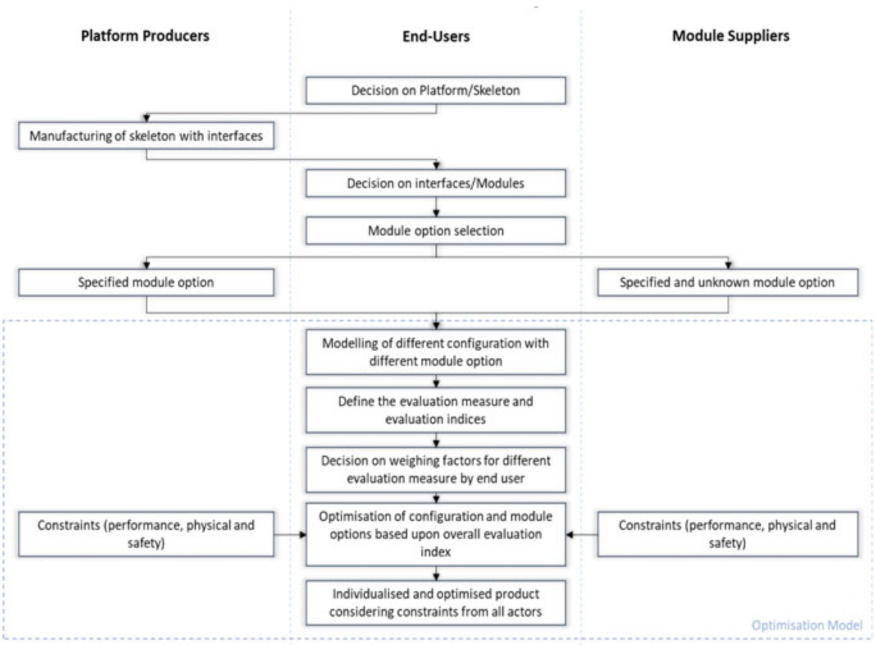

Fig. 72.2 Framework for the Innovation toolkit

- The primary requirement of the end-user can be represented by the module options of each module/interface, and it is only allowed to configure a product that offers higher-order module options than the customer requirements.

The end product is a result of participation from many module option suppliers and the end-user. This multi-directional participation causes many variations in the end product. These variations include two kinds of variation: variation of configuration in terms of different interfaces used for modules and variation of module options for selected interfaces/modules. Different module options can be denoted by different parameters. After selecting particular modules for skeleton interfaces, the second choice will be to select module options in terms of desired parameters for modules. So, a new method to model the variations of OPAP product configuration and the variations of product parameters in terms of module options is required.

72.3 Modelling of OPAP with Evaluation Measures and Evaluation Indices

Compared with traditional product customisation approaches, the variation of configuration and parameters is too high in product design for MI. Therefore, a sophisticated automated Innovation toolkit is required for modelling of OPAP with variations. Different product configurations are modelled by an AND–OR tree, as shown in Fig. 72.3. The OPAP structure can be decomposed into different sub-structures (module), connected with an AND relation. Every sub-structure can

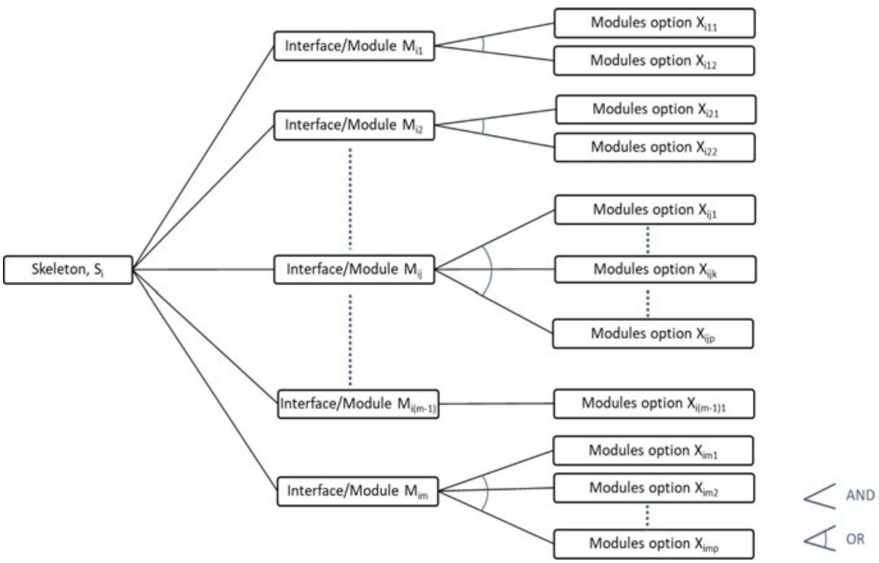

Fig. 72.3 AND–OR tree diagram for modelling different OPAP configuration

be satisfied with different module options, associated with an OR relation. Each module option in the AND–OR tree is further modelled in terms of parameters.

A feasible individualised OPAP can be obtained from the AND–OR tree through a tree-based search [14], described by a collection of nodes (Skeleton, Interfaces and modules options). In this work, the following conditions are used to generate different feasible design configurations:

1. The first node should be the root node, to be selected.
2. After selecting the root node, all the sub-nodes should be selected, if all its sub-nodes are connected with an AND relation.
3. After selecting the root node, only one of the sub-nodes should be selected, if all its sub-nodes are connected with an OR relation.

If a module node for the *i*th design configuration S_i ($i = 1, 2, \ldots..n$) is defined by M_{ij} ($j = 1, 2, \ldots.m$). This design configuration can be described as follows:

$$S_i = (M_{i1}, M_{i2}\ldots\ldots M_{im}), i = 1, 2, 3, \ldots\ldots.n \tag{72.1}$$

A module node is associated with the different module options nodes. These module option nodes represent different design parameter choices. The *k*th design parameter X_{ijk} of the module node $M_{i.j}$ is defined in the form of $M_{ij}.X_{ijk}$. Therefore, the parameters of a module node, M_{ij}, can be described as follows:

$$X_{i,j} = \left(M_{ij}.X_{ij1}, M_{ij}.X_{ij2}\ldots\ldots M_{ij}.X_{ijk}\right), \quad i = 1, 2, 3, \ldots\ldots.n, \quad and \\ j = 1, 2, 3, \ldots\ldots m \tag{72.2}$$

The parameters for the *i*th design configuration considering all involved nodes are defined by

$$X_i = (X_{i1}, X_{i2}\ldots\ldots X_{ik}), \quad i = 1, 2, 3, \ldots\ldots.n \tag{72.3}$$

The complete design solution of this configuration can be then defined,

$$D_i = (S_i, X_i), \quad i = 1, 2, 3, \ldots\ldots.n \tag{72.4}$$

If only *i*th design configuration is considered in terms of parameters, then

$$S_i = (X_{i1}, X_{i2}\ldots\ldots X_{in_i}) \tag{72.5}$$

Different product configurations are evaluated by customer satisfaction measures and indices.

72.3.1 Evaluation Measures & Evaluation Indices

An evaluation measure can be either a constant, a monotonic or a non-monotonic function of life cycle time. For this research work, these measures can be classified into two categories: performance measures, P_i and cost measures, C_i. Performance measures include efficiency, speed and resolution, whereas cost measures include product cost, module replacement cost and maintenance cost.

For a product configuration, S, with n parameters, evaluation measure in the ith evaluation aspect (measure) is defined by,

$$E_i = E_i(X_1, X_2, X_3, \ldots\ldots X_n) \tag{72.6}$$

Different evaluation measures are in different units, so these evaluation measures need to be converted into comparable evaluation indices between 0 and 1, which represents different levels of satisfaction [15]. Customer (end-user) satisfaction has been selected as an evaluation index in this work. The evaluation measure and evaluation index can be related by a linear or a nonlinear relation.

The customer satisfaction index, in the ith evaluation aspect, is defined by,

$$CS_i(X) = F_i[E_i(X)] \tag{72.7}$$

The overall customer satisfaction index can be modelled as follows:

$$\begin{aligned} CS(X) = {} & \frac{1}{W_1 + W_2 + W_3 + \cdots\cdots + W_m}[W_1 CS_1(X) \\ & + W_2 CS_2(X) + W_3 CS_3(X) + \cdots\cdots + W_m CS_m(X)] \end{aligned} \tag{72.8}$$

where W_1, $W_2, \ldots\ldots, W_m$ are m weighting factors for m evaluation indices, selected by end-users, according to their individual requirements and preferences.

72.4 Identification of the Optimal OPAP Configuration with Optimal Module Options

Since a large number of design configurations with different module options can be selected to fulfil the individualised requirement, a multi-level optimisation is employed to identify the best design configuration with optimal module options. This will maximise the satisfaction of the end-user requirements within the constraints provided by other actors of the OPAP ecosystem. Platform producers will define some constraints including functional, safety and assembly constraints. The module option providers will also provide some constraints based on their manufacturing capability, spatial and other constraints.

The overall customer satisfaction index can be considered as the optimisation objective function. The average case in which the average evaluation index is used as the objective function method is generally the most suitable for the optimal design of OPAP. The optimisation is conducted at two levels: the module options level and the configuration level.

72.4.1 Module Option Optimisation

The first level of optimisation is conducted at the module options level, i.e. selection of optimised module options into chosen interfaces, for a given configuration. In this work, module option optimisation is done with penalty-based optimisation [16] method. In the presence of constraints provided by different actors, penalty functions are used to convert a constrained optimisation problem into an unconstrained optimisation problem. The optimal parameter values for a product configuration, S_i, defined by its parameters $(X_{i1}, X_{i2} \ldots .. X_{in_i})$, using constrained optimisation approach, can be obtained as follows:

$$\max_{\mathrm{wrt} X_{i1}, X_{i2} \ldots .. X_{in_i}} CS(X_{i1}, X_{i2} \ldots .. X_{in_i}) \tag{72.9}$$

Subject to:

$$X_{ij}^L \le X_{ij} \le X_{ij}^U, \quad j = 1, 2, 3, \ldots \ldots n_i \tag{72.10}$$

$$h_{ij}(X_{i1}, X_{i2} \ldots .. X_{in_i}) = 0, \quad j = 1, 2, 3, \ldots \ldots \ldots \ldots k_i \tag{72.11}$$

$$g_{ij}(X_{i1}, X_{i2} \ldots .. X_{in_i}) = 0, \quad j = k_i + 1, k_i + 2, \ldots \ldots \ldots \ldots m_i \tag{72.12}$$

Such a constrained optimisation problem can be converted into a non-constrained optimisation problem by adding a penalty term to the objective function mentioned in the Eq. (72.9). The modified objective function with a penalty term can be defined as follows:

$$UCS_i(X_{i1}, X_{i2} \ldots .. X_{in_i}) = CS_i(X_{i1}, X_{i2} \ldots .. X_{in_i}) - \alpha . p_i(X_{i1}, X_{i2} \ldots .. X_{in_i}) \tag{72.13}$$

where $\mathrm{UCS_i}$ represents the non-constrained form of CS_i, $p_i(X_{i1}, X_{i2} \ldots .. X_{in_i})$ is the penalty term for the unconstrained objective function and φ is a multiplier constant that determines the magnitude of the penalty. The penalty term is defined as follows:

$$
\begin{aligned}
p_i(X_{i1}, X_{i2} \ldots .X_{in_i}) = & \sum_{j=1}^{k_i} \left[h_{ij}(X_{i1}, X_{i2} \ldots .X_{in_i})\right]^2 \\
& + \sum_{j=k_i+1}^{m_i} \left[g_{ij}(X_{i1}, X_{i2} \ldots .X_{in_i}) \right. \\
& \left. + \left|g_{ij}(X_{i1}, X_{i2} \ldots .X_{in_i})\right|\right]^2
\end{aligned}
\tag{72.14}
$$

72.4.2 Configuration Optimisation

The second level of optimisation is conducted at the configuration level, i.e. selection of optimised OPAP configuration for the end product. The following optimisation model is used:

$$\max_{\text{wrt} S_i^*} CS\left(S_i^*\right) \tag{72.15}$$

Subject to:

$$1 \le i \le p \tag{72.16}$$

Where S_i* is iterated among the feasible configurations with the optimised module options, i represents the i-th design configuration candidate and p is the number of all feasible design configuration candidates.

In this work, genetic programming [17] is used for configuration optimisation. Genetic programming is based on genetic algorithms and is an evolutionary method to solve an optimisation problem when solutions to the optimisation problem can be modelled by tree data structures. In genetic programming, multiple solutions are considered in the population of a generation. These solutions are called chromosomes which evolve with better evaluation measures.

The genetic programming used in this work is inspired by the work done by Hong, Hu [13]. It is formulated in the following steps:

1. Create the initial generation with n individuals. Each individual represents a feasible configuration, created randomly from the configuration AND–OR tree.
2. Obtain the overall customer satisfaction index of each individual in the current generation with optimal module options from first-level optimisation. This is used as the fitness of the corresponding individual.
3. Create a new generation from the current generation by repeating the following steps until the number of individuals in the new generation reaches n.

Reproduction. Select two parent individuals in the current generation according to their fitness measures using the roulette wheel selection method.

Crossover. Calculate the crossover probability. If a crossover operation is required, cross over the two selected parent individuals to form two new offspring individuals. Otherwise, no crossover is required.

Mutation. Calculate the mutation probability for each of the two offspring individuals. If a mutation is required, mutate the new offspring individually.

4. Select the newly created generation as the current generation.
5. If the average fitness of a generation cannot be significantly improved in the last m generations (i.e. the improvement is less than a pre-defined small number ε''), or the pre-defined maximum generation, $g_{\max}$, has been reached, the evolution process should be stopped, and the best individual in the current generation is selected as the optimal product configuration.
6. Go to Step (2).

72.5 Case Studies

The concept of product design for MI can be implemented in the market with a variety of products, but our earlier study suggests that consumer electronics and furniture industries would be a good point to start. Following this suggestion, a consumer electronics product, OPAP Smartphone (based on Google ARA) and an individualised chair (based on Axia smart chair from Nomique) are used as case studies for our work, as shown in Fig. 72.4a and b, respectively.

Fig. 72.4 **a** Google ARA, a smartphone based on OPAP [1] and **b** an individualised chair [2]

72.5.1 An OPAP Smartphone (Google ARA)

Information available in the public domain for ARA has been used to formulate the optimisation problem for an OPAP smartphone. Information is gathered from MDK (Modular development kit), a guide for the development of modular technology that Google has provided to developers [1]. Due to variations of OPAP, selected products are not the optimised one with optimal modules. Once the end-user puts forward the choice for the required module type (e.g. battery module), different smaller companies will provide different module options (e.g. different capacities). Hence, the Innovation toolkit will be employed to find the end product which provides a smartphone with optimal OPAP for the given requirements. Two feasible product configurations can be created with an AND–OR tree, as shown in Fig. 72.5.

$$S_1 = (\text{Camera Module}, \text{Battery Module}, \text{Screen Module}) \tag{72.17}$$

$$S_2 = (\text{Speaker Module}, \text{Battery Module}, \text{Screen Module}) \tag{72.18}$$

From the configuration S_1, different sub-configurations, X_1 and X_2 can be obtained with different module options, shown in Fig. 72.6.

$$X_1 = (10\,\text{MP}, 1600\,\text{mA h}, \text{AMOLED}) \tag{72.19}$$

$$X_2 = (12\,\text{MP}, 1800\,\text{mA h}, \text{LED}) \tag{72.20}$$

To obtain an optimal configuration for S_1, first-level optimisation is employed. Various evaluation measures for this case study are shown in Table 72.1. The product cost for different configurations can be determined based on individual cost from different module option suppliers. These three evaluation measures C_p, P_w and P_{bb} are converted into three customer satisfaction indices, I_p, I_w and I_{bb}, respectively.

If the weighting factors provided by end-users are x_1, x_2, and x_3 then the overall customer satisfaction index,

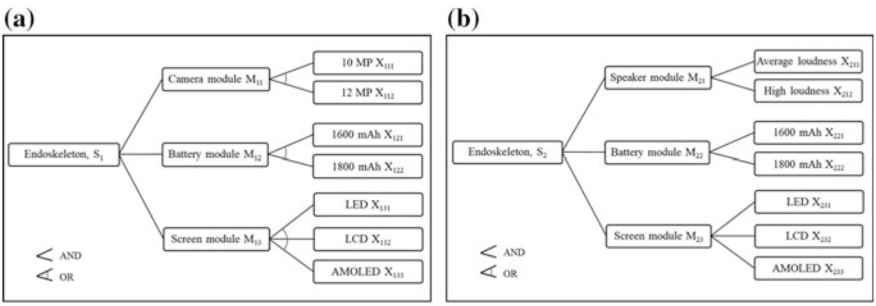

Fig. 72.5 Two different feasible configurations based upon interfaces selected by end-users

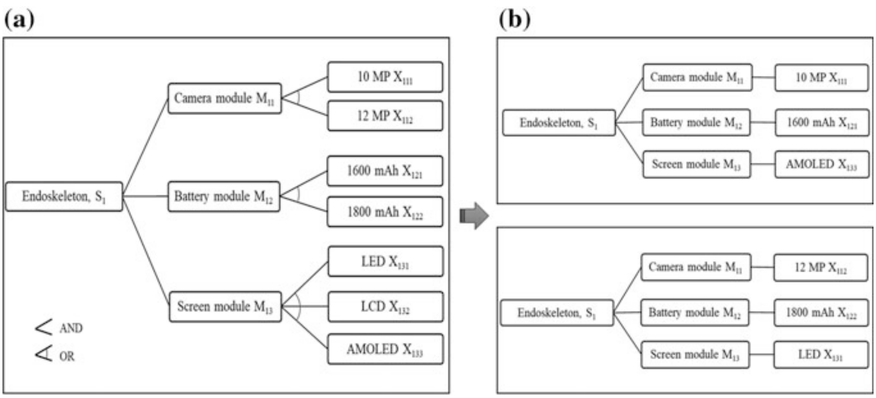

Fig. 72.6 **a** OPAP smartphone configuration, S_1 and **b** feasible product sub-configurations

Table 72.1 Customer evaluation measures selected for OPAP smartphone

Evaluation measures		Unit	Representation
Cost evaluation measure	Product cost	GBP (£)	C_{p}
Performance evaluation measure	Product weight	Grams (g)	P_{w}
	Battery backup	Hours	P_{bb}

$$CS(X) = \frac{1}{x_1 + x_2 + x_3}\left[x_1 I_{\mathrm{p}} + x_2 I_{\mathrm{w}} + x_3 I_{\mathrm{bb}}\right] \tag{72.21}$$

This equation will be used for the optimisation of customer satisfaction index with optimal module options' parameters as per Eq. (72.9). Once both configurations are with optimal module options, a genetic algorithm is employed to obtain a highly individualised and an optimal OPAP smartphone. For a larger number of variations, automated Innovation toolkit can be used.

72.5.2 An Individualised Chair (Axia Smart Chair by Nomique)

Another product, the Axia smart chair from Nomique, (see Fig. 72.4b) was selected as a case study to demonstrate the application of the OPAP and the Innovation toolkit. Different evaluation measures, e.g. chair cost and chair weight were selected for this case study and converted into respective evaluation indices to get the overall customer satisfaction index for the first level of optimisation (for optimal module

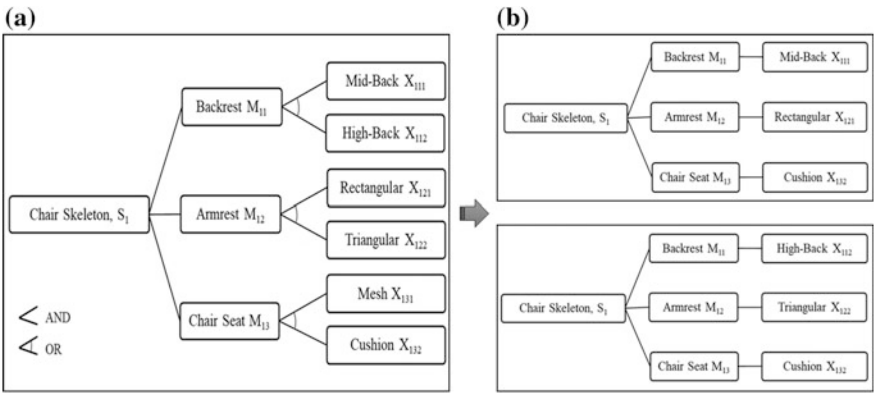

Fig. 72.7 **a** OPAP smart chair configuration and **b** feasible product sub-configurations

options). The second-level optimisation is then employed to obtain optimised and highly individualised smart chair. This case study is presented briefly in this paper just to demonstrate the effectiveness of introduced Innovation toolkit in range of products and the arising configuration are illustrated in Fig. 72.7.

72.6 Conclusion

An Innovation toolkit for identifying the optimal OPAP has been introduced. Variations in product configurations with different module options in an OPAP are modelled by nodes in an AND–OR tree. The AND–OR with different nodes for module options provides a systematic framework to model large variations of OPAP configurations. The optimal module option for every interface with maximum overall customer satisfaction index is identified by constrained optimisation, followed by configuration optimisation to identify optimal OPAP configuration out of all the feasible configurations. Two case studies are used to demonstrate the applicability of this Innovation toolkit. These case studies show that the Innovation toolkit developed in this work can readily be applied to this type of product development to obtain a highly individualised and optimised OPAP.

Product design for MI is a relatively new area where much research has to be done. To realise and implement this new approach in the market, many issues need to be addressed including optimisation of module option during the product operation stage and development of the Innovation toolkit further considering the same. Different monetary aspects, IP rights and acceptance of this approach by existing designers are also need to be tested before implementation in the market.

Acknowledgements The case studies used in this paper are based on the information available in the public domain about Google ARA and Axia smart chair by Nomique.

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Part VIII
Design Training and Education

Chapter 73
Reflection of Indian Philosophy in Design

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Abstract In design practice, we commonly believe that true knowledge is immersive and experiential. In this study, authors attempt to present their search for guiding principles from ancient Indian doctrines and different school of thoughts. The ancient philosophical doctrines state that betterment of a learner leads to realizing '*The Ultimate Truth.*' The possibilities and preparedness for the inclusion and necessary transformation of these guiding principles in the present context of design education are being further discussed.

73.1 Indian Pedagogy

The ancient Indian philosophical doctrines state that betterment of a learner leads to realizing '*The Ultimate Truth.*' It is the eternal truth, independent of place, time, or new experiences. In the commentary on Indian philosophy, Sarvepalli Radhakrishnan explained the '*Ultimate Truth*' as the '*truths of spirit and in the light of them, actual life has to be refined*' [1]. Ancient sages devoted themselves in its exploration and preached their journeys of realization. These realizations eventually formed the doctrines and enriched over time through contemporary understandings.

Vedas are the earliest doctrines, and *Upanishads* reflect the core of Indian philosophies. For easy comprehension, these philosophies were infused with stories in the epic *Ramayana* and *Mahabharata*. The *Bhagwad Gita*, from the *Mahabharata*, portrays a synthesis of practical guidelines and has relevance even in modern contexts.

Buddhism, *Jainism,* and other spiritual practices coexisted, and cross-reference between philosophies shows similarity in their core realization.

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To practice these philosophies, indigenous institutions like *Gurukuls* (teachers' home), *Mathas* (Hindu monastery), and *Viharas* (Buddhist monastery) were established. *Acharyas*, *Upadhyayas, Bhikkhus*, and *Sadhus* used to teach there with their profound knowledge [2]. *Sishya* (students) used to reside with *Gurus* (teachers) in the institutions, like a family which used to support their basic needs including food, clothing, and tools. *Sishyas* had to do some daily family responsibilities such as collecting fuel, tending cattle, gardening, etc., which instigated their hands-on experience. This synergy facilitated *sishyas* to learn from observing *gurus*' daily activity and responses to different situations. The mutual inhabitation helped to impart collaborative endeavor within *sishyas* from the early stage of life; the sense of brotherhood helped to build compassion for all. The learning was through discourse and where *sishyas* used to learn through discussions, debates, and observations. As different individuals have different inclinations and capacities, vocational education and subjects like literature and science were cultured in the ancient education system along with philosophical embracement [2]. Ancient Indian universities like *Takshashila*, *Nalanda*, and *Vikramshila,* gained worldwide fame. Interested pupil from different parts of the world flocked to Indian universities, and Indian scholars went abroad to share their knowledge.

Unfortunately, repeated invasions demolished these institutions, and numerous ancient manuscripts were lost along with oral lineages. The *Mughal Empire* controlled educational institutions with syllabus and Persian books [3]. The British rule further restricted indigenous education, confined English education only to the wealthy families, and kept the larger population uneducated for easy control over the Indian subcontinent. After Independence, no radical change is observed in pedagogy [4]. New universities, research institutes, were formed to excel in education. In these establishments, scholars are invited to pursue research with multiple scholarships to cover fees, food, and necessary daily expenses. Academia, government, and industry are actively exploring ways to refine the pedagogy for ensuring quality and equity. With the help of communication technologies, education crossed the boundary of classroom premises. Educational programs on radio and television got popularity by government initiation. Digital technology enabled classrooms with audiovisual teaching aids along with physical and virtual models. Availability of Internet throughout India enabled students to access articles, books, animations, and training modules available online. Online courses offered by foreign universities like MIT and Harvard and Indian institutions like IITs facilitated students to learn from eminent teachers across the globe.

73.2 Design Pedagogy

Indian design has its root in the art doctrines, the *Shastras* are followed even today by classical practitioners at art schools. There was no boundary between decorative art, fine art, and applied art in ancient India [5]. The current form of design evolved with industrialization. Industrial revolution mass produced items which are required to be more functional, attractive, and potent to accomplish the need of the society. Design of these items and production machinery became an utmost necessity. Today, there are various design disciplines meeting the diverse technical requirements of the industry.

During British era, craft education was part of the curricula in Indian art schools founded by the British. However, these were intended only to produce 'copyists' to serve various colonial agencies. Such schools imposed Western techniques and visual language violating the Indian tradition [5]. This pedagogy smashed the confidence of Indian artisans and craft learners and destroyed indigenous creativity and design talent. The major exception was *Sriniketan*, an experimental institution for arts, crafts, and design established by Nobel laureate Rabindranath Tagore. *Sriniketan* synthesized the work of artists and artisans on the global scale. It considered the language of the hand to be essential in the Indian context and oriented its teaching toward craft production. *Sriniketan's* ideology was compared with much later *Bauhaus* movement by different scholars.

The *Bauhaus* in Germany was the first school to formally create a curriculum for design learning and evolved and taught machine aesthetics for mass production. The pedagogic experiments were done to nurture skills and sensibilities in a design student. The learning went through the stages of experience, perception, practical ability, logical explanation, comprehension, and finally design with form follows function. The *Ulm* School of Design in Germany was the *Bauhaus* successor, emphasized the holistic, multidisciplinary context of design [6].

The first dedicated Indian design institution, National Institute of Design established in 1961 with the spirit emerged from Charles and Ray Eames's the India Report. The Eameses toured throughout India, making a careful study of the many centers of design, handicrafts, and small industries. They moved by teachings from Bhagwad Gita and the design philosophies present in simple '*Lota.*' They set the expectations from a trained designer by '*…they should be trained to help* ***others*** *solve their* ***own*** *problems*' [7]. In seventies, National Institute of Design foundation had a new look with an environmental focus that transcended the traditional inputs from the *Bauhaus*, *Ulm* and the Swiss and French schools of design [6].

During late sixties, Industrial Design Center (IDC, IIT Mumbai) set with the philosophy of fulfilling the '*physical, social and cultural needs and aspiration of the people; in a manner acceptable to the majority*' through education, practice, and propagation [8]. Instrument Design Development Centre (IDDC, IIT Delhi) founded with interdisciplinary teaching approach [9]. Much later Department of Design (DoD, IIT Guwahati) was formed with notion of '*a firm understanding, appreciation, and celebration of design*' [10]. Centre for Product Design and Manufacturing (CPDM, IISc) founded a research and technology-intensive design and manufacturing school [11]. IIT Kanpur started an interdisciplinary design program to synthesize technology and aesthetics in the service of human needs [12]. The private design institutions flourished in last decade. Among them, MAEER's MIT Institute of Design focuses on maintaining highest international quality [13], Srishti aims at the design of ecosystems that could produce creative competencies ahead of the curve [14], DSK Pune focuses on the skills required by the industry, and DYPDC wants to create leaders and innovators [15].

The industry needs a massive number of quality designers and requires 88% more designers than what is recruited now by 2020 as per the report [16]. Along with qualified designers from various design programs, some not formally trained professionals are working as professional designers in the industry. These non-qualified designers and even fresh design graduates learn on the job and gather input from various sources including discussions with experience designers, lectures, and e-resources. Internet has ample contents on design skills from design experts, studios, companies, and courses from edX and D'Source.

73.3 Design Realization from Indian Philosophy

Different industries have specific design process and responsibilities, but at the core, the method is similar. Design starts with discovering the needs through user research and discussions with marketing. The step next is exploring and ideating on possibilities with prototype tests and finally, execution of the optimized solution. These steps help to establish the rationale of design decisions and maintain quality for user-centered design. In the present scenario, the design has become teamwork with all stakeholders and the designer is the team leader. A designer envisions the future and leads others in the journey. Thus, a true designer needs to excel in both soft and technical skills. In order to achieve such a combined skill-set, an overarching vision is needed. Authors explored different doctrines and have found a scientific visionary perspective from Indian philosophy for design realization. In the ocean of Indian doctrines, some are widely known and practiced than others. Commentaries on them from different perspectives by different philosophers across centuries, continents, and fields are available which helps to translate them in an unexplored field of practice. In this study, four potential principle doctrines are selected to tune the awareness of a designer. Authors have discussed possibilities and preparedness of these doctrines in the context of design. These are secular practices regarding knowledge, truth, happiness, and attachment do not invite any conflicting emotions from different religious beliefs and ethics. However, these practices find their sublime roots in spiritual practices.

73.3.1 Combine Mind and Action

योगः कर्मसु कौशलम् [Bhagwad Gita, 2.50]

yogah karmasu kaushalam

Translation: Yog is wisdom in action.

The design is a practice, empathizing with users and comes up with optimum solutions. To reach the solution and improvement on available solutions, a designer needs to attach with users and detach with designs repeatedly. The famous verse mentioned above from *Gita* helps to understand the duty orientation and the absence of desire for rewards. This sense of duty of *Karma Yog* is useful in developing a user-centric design. *Yog* is the union of mind and action, and its culture leads to an intelligent graceful way of performing actions.

As a part of user-centric design process, designer has to understand and resonate with user. However, if the designer became too much attached with user, there would be only the ideas limited to user's knowledge and exposure. Designer is the leader of a product team having future visionary with awareness of ground reality. One in that position has to take optimized decisions considering every aspect of various stakeholders including business and development. To do so, one has to detach from the users and own ego which can be practiced through wisdom in action or *Karma Yog*. *It* guides people to cope with the pains and pleasures without selection and rejection. The practice of it will eventually increase life satisfaction, thereby creating a more stress-free team. Needless to say that there is a difference between non-attachment and non-motivation. Smart and hard work is utmost necessary for a design, but achieving a design goal depends on various things. It also includes the cultural aspect of the team to enhance the ability to cover every element to consider.

73.3.2 Energetically Working Together Absconding Jealousy

ॐ सह नाववतु। सह नौ भुनक्तु। सह वीर्यं करवावहै।
तेजस्विनावधीतमस्तु मा विद्विषावहै। ॐ शान्तिः शान्तिः शान्तिः || [Taittiriya Upanishad, verse 2.2]

Om saha nāvavatu, saha nau bhunaktu, saha vīryam karavāvahai,

tejasvi nāvadhītamastu mā vidviṣāvahai, Om śāntiḥ, śāntiḥ, śāntiḥ. [17]

Translation: Om, may we (both teacher and student) be safe, may we all be nourished, may we work together with great energy, may our study be effective, let there be no jealousy amongst us, Om, peace (in divine forces), peace (in nature), and peace (in me).

In ancient India, learning blossomed with trust and respect. This essence is present in the above-mentioned popular verse from the *Krishna Yajurveda Taittiriya Upanishad* (2.2). The philosophy of this verse is the stepping-stone of ancient pedagogy where teacher and student both take bows to each other, promise to energetically work together toward the enrichment of both, absconding jealous feeling. There was no lookdown for students with less knowledge which helps teachers to conquer false ego of superiority. This verse is practiced as a part of the opening prayer in different educational institutions even today. The prayer talks about the attitude toward the journey of design realization. The practice is to realign team members with the outlook of this prayer before starting any new activity together for the day.

This prayer starts with '*Om*' which represents the transcendental truth. Design realization reveals the possibilities toward design refinement. The final design, which is unknown at the beginning, is revealed through design realization at the end of the journey. An attitude of surrender with humility would keep the mind calm throughout the journey.

'*saha*' means together, and '*nāvavatu*' means protection from the evils, ego, jealousy, and all the negative emotions and attitudes, detrimental for the team spirit. '*bhunaktu*' means nourishment, portraying that the team should enjoy the journey and not be pressurized with limitations (e.g., time, resource). '*vīryam karavāvahai*' is to accumulate energy for the upcoming work and enjoy through the energy spent in design realization. '*tejasvi nāvadhītamastu*' means powerful from inside and would impart brilliance in a design. This brilliance is not to flaunt knowledge in design but has to be pure, enriching and beneficial in every way. '*mā*' means no and '*vidviṣāvahai*' means jealousy, which is easy to understand, however, and needs the effort to practice. The failures, challenges, and changes along the journey invoke frustration followed by anger, and the reaction from anger leads to a fight. This fight can be internal with self or external with others and eventually ruins the progress so far. This portion of the prayer guides one to keep the same positive energy till the end.

The '*Om*' and three '*śāntiḥ*' (peace) itself is a short prayer to improve peace and focus. Here, the first '*śāntiḥ*' is for any disturbance from the external world, including family, friends, society, and dear ones. The second '*śāntiḥ*' is for any disturbance from the environment around, including light, temperature, sound, connectivity, etc. The third '*śāntiḥ*' is for any internal disturbances including pain, hunger, and negative thoughts. There are always limitations, challenges, and emergency, but peace can be achieved at least to an extent by taking conscious decision and preparation. This practice will increase personal commitment toward focused and uninterrupted work.

73.3.3 Attitude Toward Brilliance

ॐ असतो मा सद्गमय । तमसो मा ज्योतिर्गमय । मृत्योर्माऽमृतं गमय ॥ [Brihadaranyaka Upanishad 1.3.28]

asato mā sadgamaya, tamaso mā jyotirgamaya, mrtyor mā amrtam gamaya

Translation: from the unreal lead me to the real, from darkness lead me to light, from death lead me to immortality [18].

In design realization, being truthful is one of the most essential characteristics and sets the direction toward enlightenment through design. The first line of this prayer asks to set a realistic goal for the team without any urge for money, fame, or even success. Accepting reality in some cases might be painful, but a design has to encounter the real problem. Considering real constraints, an organization may not afford to execute some brilliant ideas and has to consciously take pragmatic decisions.

The second line asks to initiate awareness against ignorance, which obscures mind to perceive the real situation. To consider all the possibilities, one has to be transparent and truthful to self first and then for the organization or the society. The '*jyoti*' or enlightenment of the design outcome should be enriching and beneficial in every way. The team should consciously avoid all the elements which can provoke negativity in people.

The third line depicts the concept of design life cycle. Nothing in this world is permanent and so as for design. Every design will unfold first, then is challenged by new designs, and eventually fades away. *Whatsapp* replaced *Messenger* in virtual communication. Now *Whatsapp* is adding new features as *Snapchat,* and others are coming up with new styles of communication catering unexplored needs. This design realization helps to foresight on the complete product life cycle and leads to reuse components or product recycling for a sustainable environment.

73.3.4 Completion Toward a Happy Note

ॐ सर्वे भवन्तु सुखिनः सर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तु मा कश्चिद्दुःखभाग्भवेत् । [19]

Om, sarve bhavantu sukhinaḥ, sarve santu nirāmayāḥ, sarve bhadrāṇi paśyantu mā kashchit duḥkha bhāgbhavet.

Translation: May all be happy, may all be free from illnesses, may all experience auspiciousness, may none ever feel misery.

This *Shanti Mantra* inspired from *Brihadaaranyaka Upanishad* recommends designs with positive effects on the society. '*Sarve Bhavantu*' means all become and '*Sukhi*' means happiness. It reconnects the team to empathize with users, stakeholders, community, and environment. Here, happiness comes from smooth going or progressing together. It can be best described as the center of a moving wheel where the wheel should rotate freely to keep moving. Only when the center is free, overcoming some minor obstacles in the path will be easy. A product needs to provide smooth experience as much as possible. '*Nir-Aamayaah*' means no illness which leads to good health. As a direct interpretation, a design should be free from errors.

'*Pashyantu*' means the cognition of mind where it '…*mirrors the emotions coming from all around*' [20]. It is obvious that when one sees someone crying, feels sad and when one sees happy children, feels the same happiness within. With this attitude, when the designer spreads positive vibes to close ones, it replicated in their mind. '*Duhkha*' means sadness, and in this, asking for no sadness will enhance awareness of all negative aspects. A product should not invoke pain or harm to anybody, and thus, a design has to be ergonomic as well as environment-friendly.

73.4 Conclusion

In a nutshell, design is a journey from the unknown to the final product, achieved through collaborative endeavor of the team members. In this study, authors have explored an overarching philosophy from Indian doctrines and explained its contextual relevance for design realization (Fig. 73.1). Throughout a design process, the members should align and realign themselves with this philosophical approach. As a foremost practice toward this attitude, the team should follow the path of *Karma Yog*. The journey should be inherent with the attitudes of working together. The team members must be truthful in sharing their thoughts and would realign with the truth always. The closing remarks should be the wish of happiness for others and self.

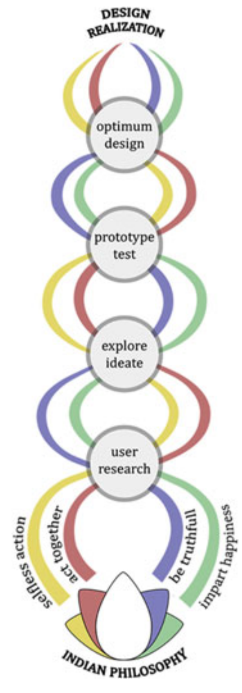

Fig. 73.1 Design realization inspired from Indian philosophy

The recommended pedagogy toward design realization needs to be self-exploratory. The guidelines should be explained in detail, and the learners would explore as per their own pace depending on individual capacity and desire. The path of *Karma Yog* in design can be experienced through assignments reflecting the personal interest and inclination of individual students. The knowledge and skills gained so far can be applied in diverse fields. This will enhance the love and respect toward people and understanding self.

The learning curve of this path is long, and one has to acclimatize through the steps of knowing, remembering, understanding, and finally resonating with it. To know the philosophy, one has to comprehend these through the translations and commentaries in their native language. It is always recommended to recite the hymns in Sanskrit to feel its aboriginal oral essence, and the rhythm of Sanskrit will be helpful for easy memorization. It is observed that people can remember and recite the full *Gita, Hanuman Chalisa, Argala Stotram* easily in Sanskrit even today. The hymns are advised to listen in traditional pronunciation, and the practice would be chanting the same by reading the hymn in own native language for reference. However, knowing the meaning in their native language will help to inherit better. Discussions and readings would help to understand it better and get familiarized with it. The philosophy needs to be incorporated in different phases in design as well to resonate with it. In actual scenario, the verses can be chanted like whispering to self before and after the work to aware the mind repeatedly. Once the mind is aware, philosophy will automatically inherit in behavior, work, and design. However, it is always recommended to share the vision but is prohibited to for a forceful recommendation.

The teachings of design realization would majorly encompass discussions, and the evaluation would be focused on the comprehensive application of the philosophy. Inclusion of philosophies in practice is more about the feel of the practitioner and cannot be measured quantitatively. However, an evaluation scale to represent qualitative score would be a good idea to share the state of practice with stakeholders. This can happen when practiced widely to get benchmarks like many other philosophical practices.

In this study, authors have explored the possibilities of the contextual appropriateness of Indian philosophy in design realization. Embracing all aspects, authors found learning module customized with personal knowledge would be a breakthrough for this pedagogy. This would guide the novice designers and the professionals. There is immense knowledge in Indian philosophy which can be explored further and incorporated in design practice. In future, these concepts will lead to a society practicing design realization to solve problems with holistic understanding and future insight.

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Chapter 74
Observing Nature—What Designers Can Learn from Biologists

Shiv Kumar Verma and Ravi Mokashi Punekar

Abstract Observation is one of the key skills necessary for learning. Observation of natural forms is the starting point for both biologists and designers to gather information in their studies. Later, biologists use this information to classify species, and designers use this information to generate new product forms. This study examines the methods and tools used by biologists and designers to observe natural forms. It also examines the similarities and differences in their approach. The research follows a descriptive methodology with data collected from various sources like published papers, books, and interviews for qualitative analysis. Finally, we propose two approaches inspired from biological studies that may help designers to generate novel product forms inspired by nature.

74.1 Introduction

"All perceiving is also thinking, all reasoning is also intuition, all observation is also invention" [1]. Many great inventors were also great observers—Leonardo da Vinci, Archimedes, James Watt, Wright brothers etc. The current study focuses on the act of observing nature and attempts to understand the methods and tools used by biologists and designers to observe natural forms. Following a descriptive methodology and qualitative analysis of the obtained data [2–4], the study explains three ways in which biologists observe natural form: observation using all five senses; observation involving the use of instruments; and observation involving the use of software. The study next discusses the approach of five acclaimed industrial designers who have attempted to find the underlying laws and principles of nature for ornamentation and design. By a study of these two approaches, the paper

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attempts to bring to light the similarities and differences in the approaches of biologists and designers. The study concludes by suggesting two new approaches on form generation inspired by biological studies that can be included in a design curriculum.

74.2 Methods and Tools Used by Biologists to Observe Natural Form

Biologists study the form of organisms for their classification, known as "Taxonomy." Morphology is the basic tool for taxonomy. With time and new technological developments, this study has evolved from just observing organisms with the naked eye to observation using instruments like scanning electron microscope and different software.

The methods and tools used by biologists to observe natural forms are discussed briefly in the following section.

74.2.1 Observation of Organisms Through Five Senses/ Goethean Science/Early Phase of Morphology

In 1790, Johann Wolfgang von Goethe, first studied morphology, the study of form and structure of an organism [5]. He followed a unique phenomenological method he called "delicate empiricism" which means "The effort to understand a thing's meaning through prolonged empathetic looking and seeing grounded in direct experience" [6]. Goethe's method is unique because it is a link between artistic and scientific domain. His observation method involved the use of all five senses. The four stages of the Goethean phenomenological method for the morphology of an organism are:

(i) Stage one: The physical/sensory information/Earth
(ii) Stage two: Time/exact sensorial imagination/water
(iii) Stage three: Gesture/inspiration/air
(iv) Stage four: Creative potency/intuition/fire.

Stage one, referred as Earth stage, is the preconceptual phase of research. It involves an exact description of the phenomenon of form and structure, through observation based on the gathering of information from all the five senses. These descriptions characterize the plant in ways that capture the many qualities apprehended by the senses in terms of its external facts. In earth mode, the researcher should experience oneself as an external observer separate from the organism. It is a difficult phase because one must see things clearly and in an unprejudiced way, which requires mental discipline.

Stage two: Time/exact sensorial imagination/the water stage of research, is about understanding and experiencing the organism's time dimension and its growth process. It is about perceiving the dynamically relational character of the organism and understanding how one quality derives from the other, one part from another e.g. relationship between seed and stem. It involves understanding the continuity of these organs not only in space but also in time. It is about not only perceiving moments externally but also taking them within, it implies perceiving them with our inner or artistic sense. Goethe called this process of cognitive participation in organism's generative movements as "exact sensorial imagination." The qualities of fluidity, sensitivity, and capacity to experience the changes of living form are used as expressive of the movement of a form through time and of imaginative cognition.

Stage three: Gesture/inspiration/air stage—In this stage, metamorphic movements are perceived as formative gestures which are also called as organisms "formative life-principles." The ideas behind the formative movements of the organism are apprehended through "airy cognition." This phase requires a deeper participation in phenomena through an inner or artistic faculty and these inner perceptions are brought to outer expression, as "Gesture sketches" through a suitable medium like visual, verbal, or even musical. The approach requires less realistic and more expressive art forms. The mode of cognition associated with the air phase is called "Inspirational." These gestures of organic forms are not perceived as empirical facts or movements in time, but one has to inspire them with artistic cognition to allow their meanings to surface.

Stage four: Creative potency/intuition/fire stage—The gestures obtained in the third stage are further distilled by intuitive mode, which is another mode of observation. This stage is the most inner way of experiencing the organism, and intuitive perceptions can be expressed through any medium capable of transmitting potent meanings like art. Intuitive perception is thinking from the whole to the part. This is the fire stage. The fire has the character of intensity and self-generated activity. These qualities are experienced externally as warmth and internally as the immediate warmth of identification that one feels when one has made contact with a living being's inner impulse. Poetry and paintings can be used as a way of actualizing this fire stage.

74.2.2 Use of Instruments in Morphology

With time, biologists like Darwin included basic tools like magnifying glass, simple microscope, and compound microscope as scientific tools in their studies to observe microorganisms. Although Darwin had excellent observational skills, he made great discoveries using basic scientific tools like magnifying glass and notebooks to record his observation in the form of sketches and texts [7].

Illustrations of the observed features played a key role in morphology. Adrian D. Bell in his book "Plant Form An Illustrated Guide to Flowering Plant Morphology" quoted Arber's saying as "Artistic expression offers a mode of translation of sense data into thought, without subjecting them to the narrowing influence of an inadequate verbal framework; the verb 'to illustrate' retains, in this sense, something of its ancient meaning—'to illuminate'." [8, 9].

The modern methods include the combination of illustrative methods to record the aspects of plant morphology, which includes photographs, line drawings, stick diagram, and ground plan (Fig. 74.1) [9]. This combination of methods helps to gather maximum information about the subject under investigation. Color photographs are preferred over black and white as the brain faces some troubles in identifying different gray tones (Fig. 74.1a). Line drawings could be an accurate detailed representation of specimen or drawings with minimum line work for more clarity (Fig. 74.1b). In stick diagram, the organs are represented as a fine line and symbols, ignoring their thickness. Stick diagrams are useful to covey plant construction with minimum background noise (Fig. 74.1c). Ground plan also called as floral diagrams for flowers, which depict shoot system or flowers as if viewed from directly above. It reveals the underlying patterns of symmetry in the specimen (Fig. 74.1d).

Before the 1880s, animal morphology was purely descriptive science explaining the relationship between coexistence and successive form-states of same or different animals. In the 1880s, W. Roux gave the name "Entwicklungsmechanik" as a new science of causal morphology, which means the investigation of the development of form and not the mode of action of a formed mechanism, which is done through mechanistic methods [10]. The morphological approach in modern taxonomy aims to understand the evolutionary histories of organisms for which they use new techniques to discover fine structures of various morphological characters. These new techniques and methods involve the use of scanning electron microscope, transmission electron microscope, and ultraviolet rays, providing a high-quality three-dimensional image with greater magnification, which helps in the discovery of new characters [11].

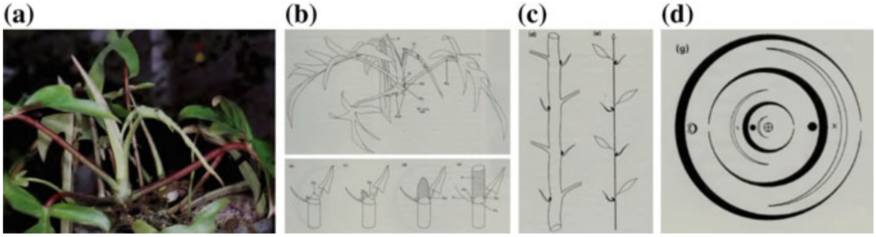

Fig. 74.1 Illustrative methods for plant morphology [9]. **a** photograph, **b** line drawing, **c** stick diagram, and **d** ground plan

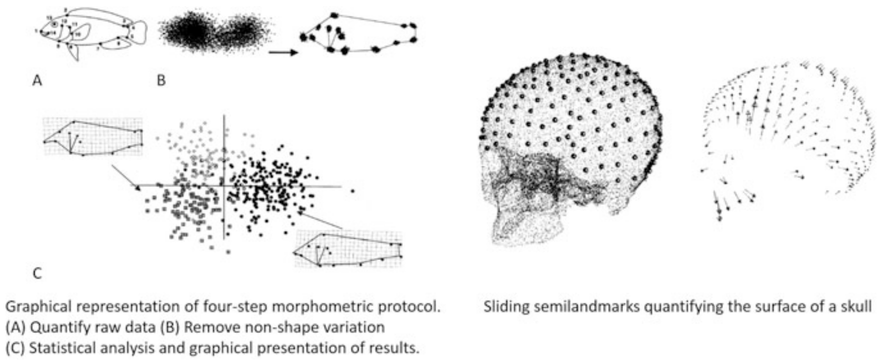

Fig. 74.2 Geometric morphometrics methods [13]

74.2.3 Use of Software in Morphology

The basic steps in the process to understand the morphological changes in an organism includes counting, recording the presence or absence, and performing simple linear measurement of a phenotypic trait to more complex method aided by a statistical framework such as geometric morphometrics [12]. Morphometrics is the study of shape variation and its covariation with other variables [13]. The two approaches of morphometrics are traditional morphometrics and geometric morphometrics. Traditional morphometrics involves the measurement of linear distances and the use of multivariate statistical tools. Geometric morphometrics methods use either outline methods or landmark methods to describe a shape (Fig. 74.2) [13]. Geometric morphometric involves the use of both instruments as well as software. During data collection, biologists use calipers, digitizing tablets, 3D digitizers, etc. and for analysis, they use statistical software packages like edgewarp, statistical analysis system (SAS), MATLAB, etc. [14].

74.3 Methods and Tools Used by Designers to Observe Natural Form

The current section is focused on understanding the approach of designers to observe natural form. For this study, data of five designers reputed for their practice of taking inspiration from nature for their designs were examined from published sources and the internet: Owen Jones, Christopher Dresser, Arthur Heygate Mackmurdo, Luigi Colani, and Ross Lovegrove.

74.3.1 Observing Principles and Laws Which Regulate the Arrangement of Form in Nature

Owen Jones, an architect, designer, and design theorist, is known for his contributions in color theory. In his book "Grammar of Ornament" [15] Jones explains how ornaments are based on the observation of principles, which regulate the arrangement of form in nature. He states that true art lies in idealizing and not copying the forms of nature. Jones suggests that one should discover the underlying principles and grammar in nature and draw inspiration to generate new visual forms [16]. Among thirty-seven principles on "Arrangement of form and color in architecture and the decorative arts," Proposition 11, 12, and 13 are closely related to nature. Proposition 11 states that "In surface decoration all lines should flow out of a parent stem. Every ornament, however distant, should be traced to its branch and roots" (Fig. 74.3a); Proposition 12 states that—"All junctions of curved lines with curved or of curved lines with straight should be tangential to each other" (Fig. 74.3b) and according to Proposition 13—"Flowers or other natural objects should not be used as ornaments, but conventional representations founded upon them sufficiently suggestive to convey the intended image to the mind without destroying the unity of object they are employed to decorate" as illustrated in Fig. 74.3c [16].

Taking the example of a chestnut leaf, Jones says that these natural laws are so universal that one can find them in all natural forms (Fig. 74.3d). The perfect proportional distribution of areas, radiation from the parent stem, tangential curvature of lines, and even distribution of surface decoration can be seen in almost all types of leaves. Referring to one of his plates on flowers (Fig. 74.3e); Jones says, "The basis of all forms is geometry." The symmetry and regularity that one can see in flower is a result of an impulse that starts from the center of the flower with equal force and stops at equal distance, which forms the surface [16].

74.3.2 Observing Geometric Principles of Order in Nature

Art botany is a "form of applied art based on the observation of order in nature" [17]. Christopher Dresser, an industrial designer and design theorist was Professor

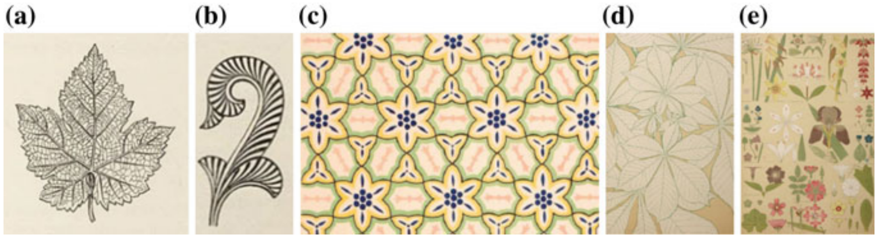

Fig. 74.3 llustrations from the book—grammar of ornaments [16]

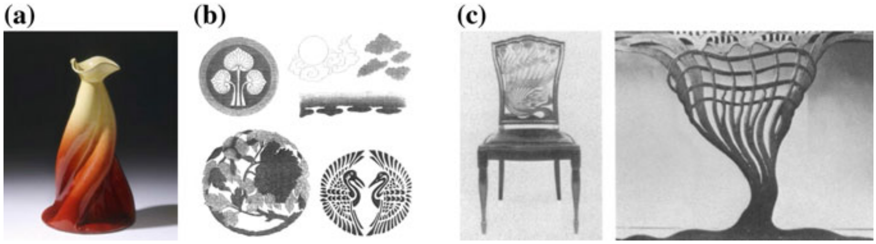

Fig. 74.4 **a** Vase designed by Christopher Dresser [18], **b** illustrations by Christopher Dresser on Japanese Ornamentation [17], and **c** work of Arthur Heygate Mackmurdo [19]

of Artistic Botany in the Department of Science and Art, South Kensington. As a successful botanical draftsman and researcher of plant morphology, he used descriptive botany in an architectural idiom, illustrating plants in the plan and sectional views. Dresser was inspired by the underlying order of nature—Refer Plate No. 8 in the final chapter "Leaves & Flowers from Nature" of Owen Jones book "The Grammar of Ornament" (Fig. 74.3e). He suggests that while following nature one should not just imitate appearance, but apply its inherent laws and geometric principles of order (Fig. 74.4a).

Dresser was an acute observer and observed Japanese designs and art based on his botanical understanding as well as his thinking on symmetry, nature, and ornament. He observed a perfect order in the distribution of plants in the Japanese ornament and the way they use symmetry in their designs (Fig. 74.4b). His evolving knowledge on order and laws of nature was the basis of his designs and writings [17].

74.3.3 Observing the Laws of Nature

Arthur Heygate Mackmurdo was an architect and designer renowned for his botanical designs. Most of his work is based on his concepts of "law of nature." The two inseparable elements of Mackmurdo's designs are "a distinctive use of botanical imagery and function of that imagery as the symbolic embodiment of a constructive and ordering force in the process of nature" [19]. The uniqueness in the approach of Mackmurdo's lies in the way he subordinates the data of nature to the rules of abstraction and requirement of decorative design, which made him strive for more profound knowledge of nature and understand the abstract principles underlying the concrete images of nature. These abstract principles are also reflected in his designs (Fig. 74.4c) where all the natural elements in the composition display swinging rhythmic motion in a response to an external force of air or water. Mackmurdo's botanical designs possess qualities like dynamic rhythms, reciprocal action of internal and external forces, irregularity, arbitrariness, and economy of form, which shows a close connection with the Herbert Spencer's principle of organic evolution derived from observation of natural phenomena [19].

74.3.4 Observing External Forms and Shapes

Luigi Colani is a German industrial designer known for his bio-designs and bio-dynamic forms. He has designed products that are characterized by round and organic forms inspired by nature [20]. He believes that the existing form of organisms is a result of millions of years of evolution that are highly functional. This is a basic principle for his biodynamic forms. As a bio-designer, his designs are 80–90% nature and he translates nature into intelligent things [21]. He explains his process as the development of ideas through sketches and models. He looks for shapes in nature to get inspirations [22]. The bio-design products of Colani display a close resemblance with nature in terms of shape and forms. The form of universal mobile charger Anyfix and its dynamic legs are inspired by Dytiskus Marginalis (Fig. 74.5a) [22], mega passenger aircraft has a form of shark (Fig. 74.5b) and the Squirrel Colani Cup that looks like a squirrel (Fig. 74.5c) are a few examples [23].

74.3.5 Observing Natural Growth Patterns

Ross Lovegrove is a Welsh industrial designer also known as "Captain Organic," for his design philosophy of "Organic Design" [24]. He creates intelligent forms through his concept of DNA: design, nature, and art. Considering impressionism as a valuable art form, he describes his digital drawing of water as his impression of water (Fig. 74.6a). Mostly influenced by the observation of nature, he draws what he visualizes [25]. Inspired by architects like Zaha Hadid, he reinvented his process of form creation making use of digital technologies like parametric software, 3D printers, and 3D scanners. Having a special interest in bones and fossils, he says that these things have evolved over many years and he always tries to understand the natural growth patterns and beautiful forms that nature creates. He scanned bones for a three-dimensional organic structure and rapid prototyped them to a bigger scale (Fig. 74.6b). By combining engineering with biological thinking, he produced a bone-like structure with the interlocution of elements (Fig. 74.6c). He

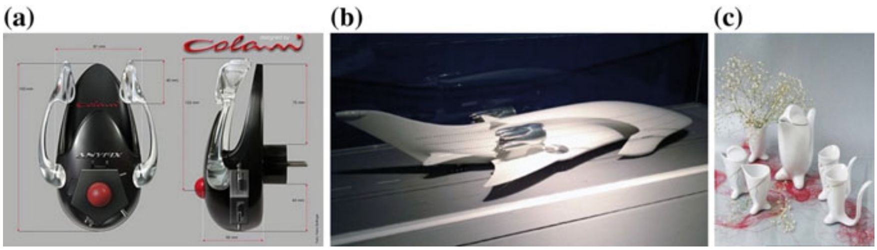

Fig. 74.5 Designs by Luigi Colani. **a** Anyfix [22], **b** mega passenger aircraft [23], and **c** Squirrel Colani cup [23]

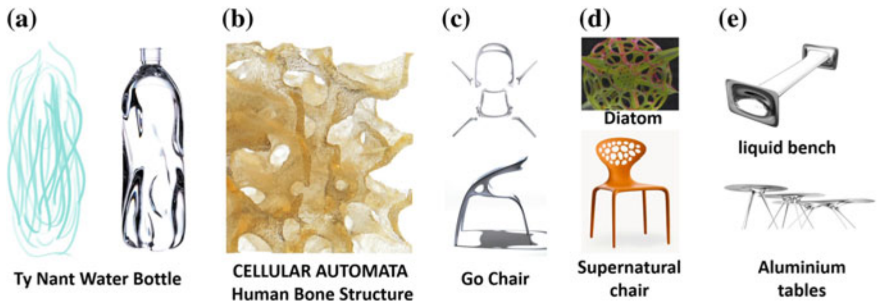

Fig. 74.6 Designs by Ross Lovegrove [24, 26]

explains "Organic Essentialism"—a principle of reducing a form to its minimum material mass [25], by stating that nature drills holes in things and takes away extra material that is not required. When such natural principles are applied in designing of products, one can generate a fluidic form with varied material properties within a single form. He looks into the data images of microorganisms like a diatom, which are not visible to the naked eyes to see that these microscopic organisms are also cored out and the remaining material is something that is actually required (Fig. 74.6d). He suggests that such structures can be used for future products (Fig. 74.6d). He has worked on products with single surface structures that grow. The stretch and flow of the single surface structure are analogically referred to growth in nature (Fig. 74.6e) [24].

74.4 Similarities and Differences in the Approach of Biologists and Designers

The understanding of methods and tools of biologists and designers to observe natural form in previous sections can be used in a comparative study that focuses on the similarities and differences existing in their approach. The first similarity is the use of sketching to record observations. For biologists, sketching the observed organism is an important mode of recording observations and it has been practiced in both the early phases of morphology (Goethean science) and in modern methods, which includes the combination of illustrative methods like line drawings, stick diagram, and ground plan. For designers, sketching is an integral part of the design process and a mode of ideation. The illustrations by Owen Jones and Christopher Dresser in their work explain the importance of sketching in their design process. Luigi Colani and Ross Lovegrove use sketching to develop their ideas. The second similarity is the abstraction. Aristotle defined abstraction as cutting off a part of being and making a science about it [27]. In art, abstraction means "the act of drawing out the essential qualities in a thing, a series of things, or a situation" [28]. Biologist uses abstraction to reduce background noise and extra information that is not required. Stick diagram, ground plan, and morphometric data are the form of abstraction that biologist use in their work. Designers use abstraction to create novel forms. The major difference in their approach is the aim of their studies. Biologists in their approach aim to find the causes that lead to the development of form, whereas industrial designers are involved in the act of creation of new forms.

74.5 What Designers Can Learn from Biologists

From the inception of industrial design, designers have been using their biological knowledge to create new forms. Owen Jones used geometric principles that exist in nature and illustrated his observations in sectional and plan views, which are similar to the representations by biologists in the stick diagram and ground plan. Christopher Dresser was the trained botanist who used his botanical knowledge to observe and create new ornaments and product forms. Luigi Colani translates streamlined and aerodynamic features of natural forms into product forms. Generative design uses the principles of nature to find the optimum solution using cloud computing. These day's designers are not only using principles and laws of nature, but also the instruments that biologists use. Ross Lovegrove makes use of such instruments to explore the microscopic structures for his designs: Diatom chair and cellular automata. Designers can apply biological knowledge in form generation process in many possible ways. One can learn the evolutionary pattern of any organism through stick diagram and can apply that evolutionary pattern to a product form to evolve its future versions. Use of geometric morphometrics software could be a creative way to generate new product forms. Designers can learn to observe the behavior of animals, also the changes in the external form associated with that behavioral change, and can apply that observation to generate new product forms. The detailed discussion on such methods in this paper aims to motivate and provide a vision to the designers to explore the use of biological studies in the creative activity of form generation. In the next sections, we present examples in which we propose two new approaches inspired by biological studies that can be explored in a design curriculum on form generation.

In the traditional method of observation that designers follow, they only identify the external form elements and aesthetic patterns [29]. The proposed methods will help designers to understand the underlying principles of form transformation in natural form and apply them to generate new product forms. The outcome of the proposed methods that are nature-inspired product forms may or may not resemble the natural inspirational form but will be based on the underlying principles of form transformations found in a natural form.

74.5.1 An Approach to Nature Inspired Product Form Based on Thompson's Theory

This proposed approach is based on the D'Arcy Thompson's theory of transformation. In his book "On Growth and Form," Thompson described the differences in the form of related animals by means of simple mathematical transformations [30]. Based on his method, we attempted to apply such a principle of form transformations to a product–the earbud, in order to explore new ways of form generation based on biological studies (Fig. 74.8a). In a regular classroom exercise on form generation, first students must be introduced to the Thompson's method to study the transformation of natural form following Cartesian transformations and later students can use those grids to transform and generate a new range of product form variations.

74.5.2 An Approach Based on Animal Behavior

In this method, we examined the change in the form of an organism as a result of the change in its behavior. Janine Benyus defines behavior as a survival maneuver in her book "The Secret Language of Animals" [31]. Desmond Morris in his book "Animal Watching—A field guide to animal behavior" mentions that every piece of behavior functions in some way to improve the chances of survival of the animal [32]. Different animals exhibit different behaviors. However, the common survival moves and common behaviors can be arranged under broad categories like locomotion, feeding, body maintenance, shelter building, sleeping, escape/defense behavior, courtship displays, parental care, and play behavior [31, 32].

Escape / Defense Behavior				Related keywords for Product Personality or Product Attributes
Behavior description		Animals	Form analysis (Observed changes in animal form)	
3 basic strategies for escape behavior	Freeze – camouflage is helpful in this case	Bittern, Hares, Young Antelope, Tree Squirrels, Woodpeckers	Static form, balanced form,	Hard, Uncomfortable, Serious, Aggressive, Protective, Fear and Speedy.
	Flee – fast escape actions, speed	Deer, Antelopes, Impala, Oryx	Form elements come close to each other to form an single overall form with a directional movement and then expand with same directional movement	
	Fight – Use of horns, beaks, body transformations.	Toad-inflated, Frilled lizard	Transformation of form to increase overall size.	

Fig. 74.7 Observation sheet—to record information about behavior and its associated changes in the form of an animal

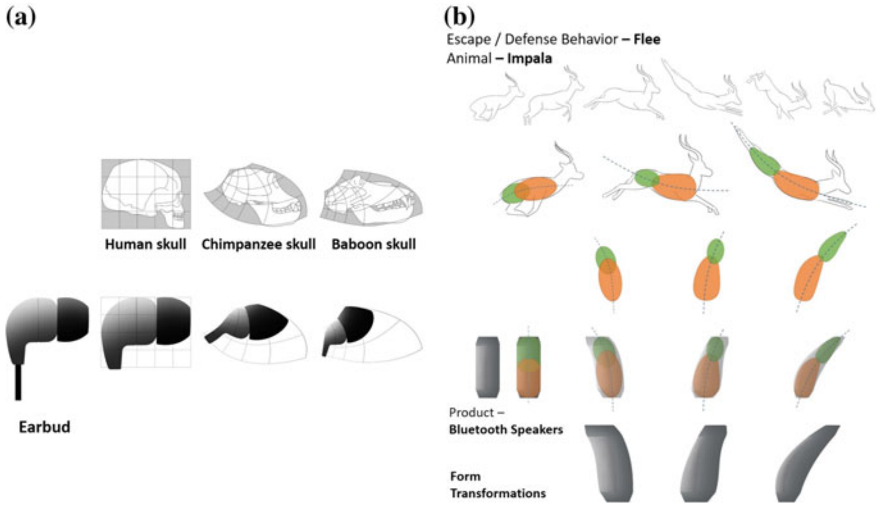

Fig. 74.8 **a** Transformation in the form of earbud following Thompson's transformation of the skull and **b** transformation in the form of Bluetooth speakers following the form transformation of Impala

It is suggested that for a classroom exercise of form generation, students can be asked to select one of the common behaviors mentioned above for their study. They can analyze the form transformation of an animal under that behavior and can tabulate their observations as shown in Fig. 74.7. Based on these close observations, they can apply these underlying transformation principles/observations to generate the desired product expression. An example is illustrated in Fig. 74.8b. This approach will help designers to make the product form more expressive and communicative.

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Chapter 75
Learning Through Gaming?

Comparative Innovative Educational Games of Children (An On-Going Research Project)

Siddhesh Sushil Shirsekar

Abstract Learning fluently is an extremely important skill for all children to acquire. Many children are growing up in diverse bilingual or multilingual contexts and learning to speak and read in more than one language. It is crucial that children who are having problems in learning due to phonological difficulties are identified early, and that appropriate screening instruments are designed in their native language(s). Appropriate intervention programs can then be implemented. In bilingual and multilingual children, the situation is even more complex as they have to learn using different writing systems, often concurrently. As bilingual children can have different phonological awareness profiles in their two languages, it is desirable to assess children in both of the languages spoken. In relation to multilingual children, assessing phonological and reading skills becomes an even more complex task. The current paper explores various parameters which impart knowledge through games by comparing two different scripts (Roman and Devanagari) as learning during childhood.

75.1 Introduction

Learning fluently is an extremely important skill for all children to acquire. Many children are growing up in diverse bilingual or multilingual contexts and learning to speak and read in more than one language. It is crucial that children who are having problems in learning due to phonological difficulties are identified early, and that appropriate screening instruments are designed in their native language(s). Appropriate intervention programs can then be implemented. In bilingual and multilingual children, the situation is even more complex as they have to learn using different writing systems, often concurrently. As bilingual children can have different phonological awareness profiles in their two languages, it is desirable to assess children in both of the languages spoken. In relation to multilingual children,

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assessing phonological and reading skills becomes an even more complex task [1]. The current paper explores various parameters which impart knowledge through games by comparing two different scripts (Roman and Devanagari) as learning during childhood.

75.2 Problem Definition

Becoming literate is a very imperative skill to acquire, and children who fail to learn to read and write in general undergo the long-term corollaries of this disability. It is critical that problems or delays in reading are detected early, so that appropriate intervention programs can be instigated. However, literacy skills and their acquisition vary across languages and across printed forms of languages. It is therefore crucial that the assessment instruments used to screen children are developed in the child's own language or languages [1]. This is crucial for children learning to read different languages throughout the world, and in particular for children growing up in multilingual contexts where children learn to speak and read in more than one language.

75.2.1 Germ of This Paper

The problem as mentioned above the learning should happen in child's own language opened a new dimension of comparative study of different existing games in Indian market. Along with comparative study between conservative education forum and playful method in education so as to aid the learning methodologies.

75.3 Objective

To study various games that imparts knowledge in the existing Indian market. Games impart fun and knowledge during play. The current paper is a hypothesis to associate the Roman script and Devanagari script acquisition methodologies and their mediums. Also investigate whether Devanagari script games are individual innovative applications or a replica of Roman script games. Among the vast variety of games, the concepts presented here can find applications as well as contradictions in board games, outdoor games, video games, imaginative play, and professional games [2].

75.3.1 Learning During Play

Every game involves a learning process. In this context, we have to note that the meaning of "learning" is not limited to the formal education alone. It also includes acquiring several qualities which are not part of the normal education curriculum.

Considering the age levels from kinder gardens till growing and developing ages (till five years), there are many games manufactured for the development of the child. Living in a diverse nation and considering the education system English is language of instruction, teaching and learning, English as it is progressed in school as first language (EFL). Individuals who speak and use two languages on a regular basis are often referred to as being bilingual [1]. If we are bilingual, or second languages and first then we are multilingual. (We refer to any language learned after the first as a second language, even if it is the third or fourth you have learned.) According to Dr. Kathleen Alfano, former director of child research at Fisher price; variety of toys for learning, not just those labeled as such. In some way, all toys have some learning benefits. In fact, you'd be amazed by what children can learn from even the most basic toys. For example, blocks and building toys provide exposure to math concepts such as how many, more than and less than. They also offer experience in the critical thinking skill of estimation, in addition to enhancing problem-solving skills and creative thinking. Puzzles, stacking toys, shape sorters, and many other toys foster eye–hand coordination and fine motor development—important skills for learning to write. Further Dr adds that books and toys that focus on letters, words and phonics help develop literacy, language, and reading skills. Toys are first and foremost all about having fun and providing pleasure and enjoyment to children. Because most toys are intrinsically developmental, providing the right toy at the right time may be all that is needed to stimulate learning [3].

75.3.2 Exuberance and Play

Considering the gaming system where the core being fun. Unexpected challenges thrown up by the game play (the system) and the process of trying to overcome, these challenges, by certain actions within the structure of the game (rules), are what impart amusement (Fig. 75.1).

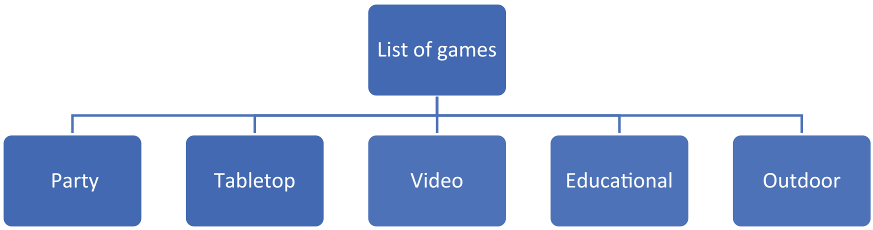

Fig. 75.1 List of games [2]

According to the targeted age, one falls in the respective categories by their choice. Considering the current scenario of learning environment, table top, video, and educational games are the keys to development of a child.

Table top games	Video games	Educational games
Board	Arcade	Letter
Card	Computer	Mathematical
Miniature	Online	Parlor
Dice (*Chance*)	*Chance*	*Memory* (*Chance*)
Pencil–Paper	Handheld	Locative
Tile	Mobile	Color
Role	Mini	Spelling
Carom	Flash	Interactive
Strategy	*Strategy*	*Strategy*
Real time	Casual	Reading
Thematic	Escape	Recognition

For any game, the most important element required is skill to accomplish it. Therefore, there are three important basic factors, which determine the suitability of a game for any particular age group. They are CHANCE, SKILL, and STRATEGY.

75.4 Game Analysis

75.4.1 Technology Applications

Technology playing a vital role in learning process electronic gadgets is in the forefront. Below are top 10 mobile learning games for children below 5 years to learn roman alphabets (Fig. 75.2).

The games above involve different aspects such as care, learning, recognition, strategy, exploring, coloring, interaction, and sound.

Following are the advantages of playful educational environment.

1. Play-way methods take into consideration the overall development of the child.
2. Holistic development approach takes into consideration, sensory-motor, physical, cognitive as well as social-emotional development.
3. Enables each child to set up independent learning goal.
4. Is learner-centric and not teacher-centric.
5. Emphasizes on learning by doing and helps in better internalization.
6. Enables peer group learning in which differently abled children would actually enhance the learning of normal children too.
7. Enables integrated learning, i.e., learning of different skills and knowledge base from one source.

Fig. 75.2 Top 10 mobile learning games [5]

For Devanagari learning mobile apps restricted to interaction and innovative execution methods which can be observed below. However, these are not the ideal examples but easily accessible medium of learning when investigated by tutors (Fig. 75.3).

Fig. 75.3 Devanagari mobile apps

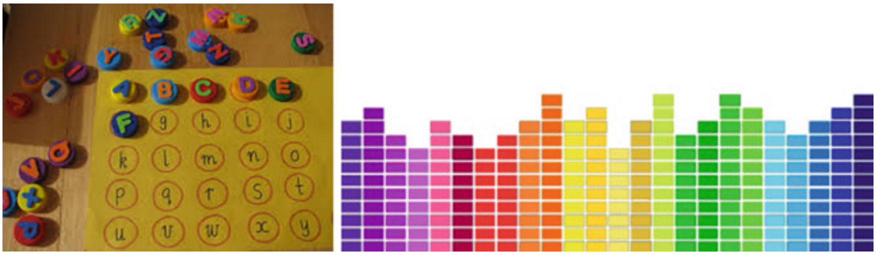

Fig. 75.4 Simple Roman alphabet game with its color palate [6]

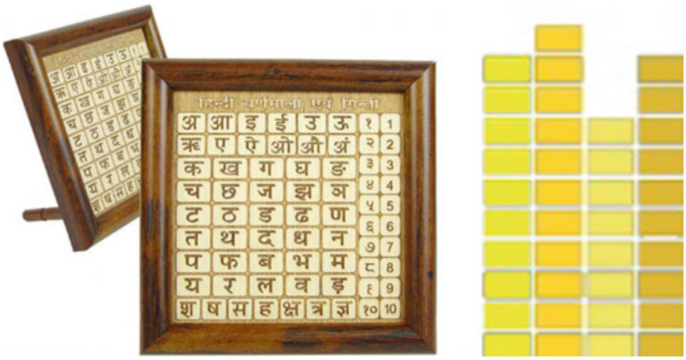

Fig. 75.5 Simple Devanagari alphabet recognition with its color palate [3]

75.4.2 *Color Palate*

Color Palate of roman alphabets.

Colors play an important role in learning. Vibrant the color palate more attraction is gained. A basic example of roman alphabets and color used below (Fig. 75.4).

Color Palate of Devanagari alphabet game is less attractive as compared to Roman (Fig. 75.5).

75.5 Statement

The new parameters of acquiring Devanagari script with Roman script seems insufficient to learn in a more creative way. This paper attempts to state hypothesis to compare the existing ways of learning respective scripts. Are the new ways of learning Devanagari innovative and rooted to fundamentals or just a replica of roman learning games?

75.6 Approach

To test the parameters of learning, we compared few fundamental existing games. Those were easily available for both the scripts with following stages like rewriting on the letterform or tracing the letterform and phonetic association the scripts. These are essential methods to learn any script.

75.6.1 Tracing the Letterform

See. Fig. 75.6.

75.6.2 Lessening the Sensitivity of the Letterform

See Fig. 75.7.

75.6.3 Phonetic Association of Devanagari

See Fig. 75.8.

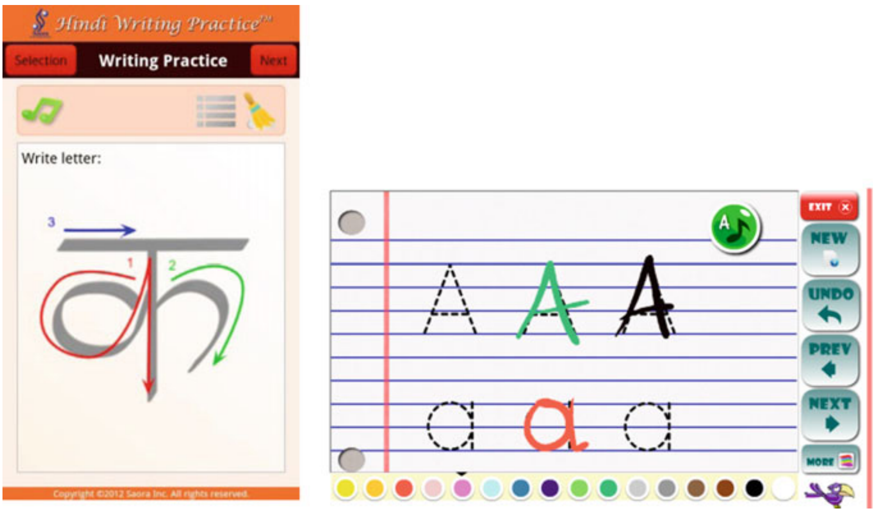

Fig. 75.6 Tracing the Devanagari consonant ‘Ka’ without the starting point and imitating roman application

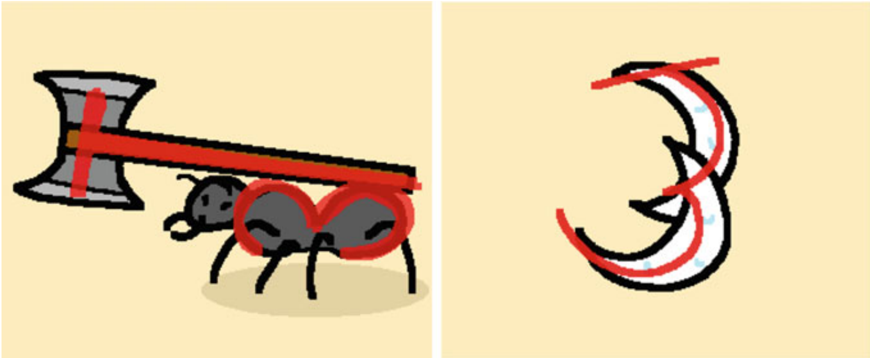

Fig. 75.7 Devanagari Vowels ‘a’ and ‘u’ with distorted structure [7]

a	luck	लक
ā	lock	लाक
i	lick	लिक
ī	leak	लीक
u	look	लुक
ū	Luke	लूक
ṛ	brick	बृक
e / ē	'lec'ture	लेक
ai	lake	लैक
o / ō	'loc'us	लोक
au	loud	लौद

Fig. 75.8 Academic references in MFL and EFL (Marathi as first language and English as first language)

75.7 Observation

1. Scripts differ in appearance, the visual form of its symbol set.
2. Symbol units, called akshara, represent sounds at the level of both a syllable and a phoneme [4].
3. In contrast, the alphabetic scripts of languages like English represent sounds at the level of the phoneme.
4. Interdependency on scripts to learn individual script. (Transfer of learning)
5. As bilingual children can have different phonological awareness profiles in their two languages, it is desirable to assess children in both of the languages spoken with individual system rather than replicating each other (Figs. 75.9 and 75.10).

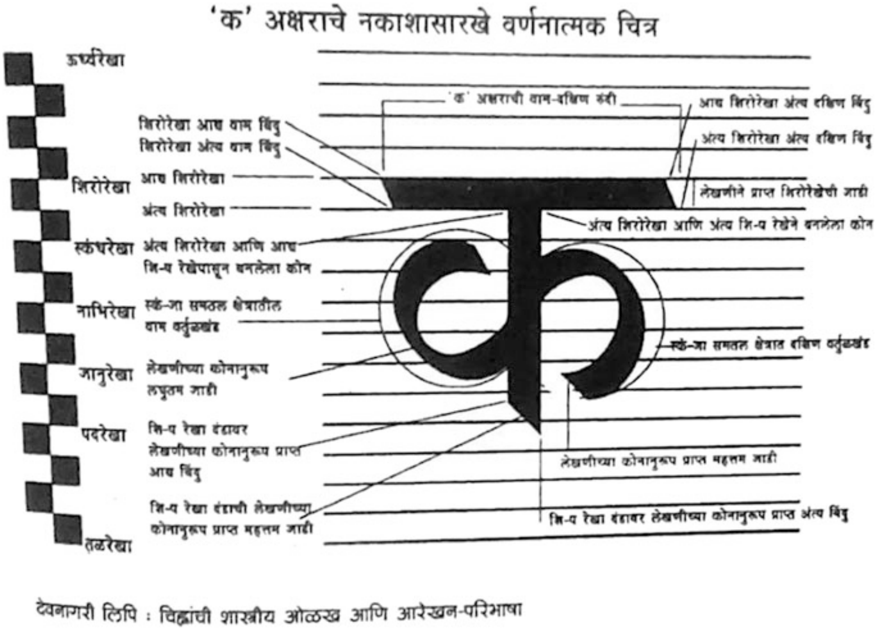

Fig. 75.9 Construction and anatomy of Devanagari letterform by Prof. Mukund Gokhale [6]

Latin Script	Devanagari Script
H + I = HI	ह् + इ = हि (vowel = इ; vowel diacritic = ि)
H + U = HU	ह् + उ = हु (vowel = उ; vowel diacritic = ु)
H + E = HE	ह् + ए = हे (vowel = ए; vowel diacritic = े)

Fig. 75.10 Typography of Devanagari [6]

75.8 Synthesis

Analyzing the games described above the following segment will explore its reasons as why they were chosen and what the outcomes were. Considering the conservative teaching forum and playful education techniques, the above games are more effective.

In a conservative school, the instruction imparted places emphasis on primarily developing reasoning abilities and in acquiring knowledge. This is done through an educator-led system where instructor imparts knowledge and children are supposed

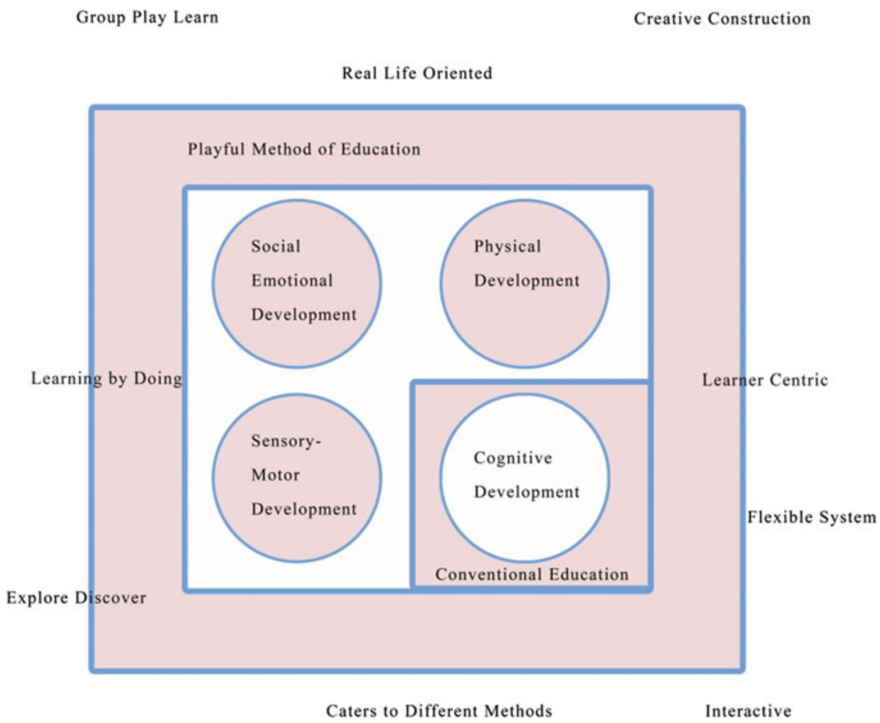

Fig. 75.11 Acquiring and expansion in conservative education and playful method

to evoke the same. The edification objectives are set by the educator and all the children are assumed to accomplish the same goals. This often leads to a competitive environment in course. The motivation for students is most often praise from mentor or in the form of rank/prize. On the divergent, a playful method is learner centric. Each child is able to set distinct goals of learning according to his/her aptitude and level. The child acquires to enjoy the whole spirit of learning and discovery, and this becomes a pattern of learning even at a later stage. The learning is not limited to cognitive development but considers the overall development of the child. The learning is closer to real life and is interactive in nature. This ensures better internalization of learning. Below is pictorial chart representation of the entire process of learning which caters to different levels of acquiring respective scripts. The playful method is more reliable as conservative teaching forum; thus, we need different innovative individual games to learn (Fig. 75.11).

75.9 Conclusion

It is extremely important that children in both monolingual and multilingual contexts become literate in a country like India. The results of the present research suggest that to enhance the acquisition to Devanagari recognition we need to develop individual learning games rather that temporary solutions. The learning through gaming should be more toward fundamental structures along with phonological base. Thus, the Devanagari script requires more individual approach and designing sensitive articulated study material. From the above inference, it can be observed that Roman script offers more dimensions than Devanagari script, thereby creating a lacuna in absorbing Devanagari script hence creating a need of individual learning.

The possibilities are infinite and never ending process. There is always scope for development in the existing research paper for self-development and society.

75.10 Approaching Opportunity

Further, the research paper can give possibilities to device different innovative games to acquire Devanagari script with book diversities with vocabularies, abundant attitudes perhaps functional through devices and techniques.

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Chapter 76
Planning to Enhance Student Learning Outcomes on Innovation Design Projects

Yi Teng Shih and Willy D. Sher

Abstract Design studio is the central learning environment for students in design schools. For the major design project, various topic selections can lead to dissimilar design journeys. This module was taught for the first time at one of the international universities in China campus in the 2015 spring semester. After completing the teaching, students suggested that more critiques help them to acquire design knowledge and manage their time more effectively. We adopted their suggestions. However, the learning outcomes in 2016 were not as good as those of the preceding year. To address this issue, we proposed Kolb's experiential learning cycle as a framework to develop assessment strategies for various design stages, and we argued that assessment strategies designed based on this framework enhance student learning outcomes. We illustrated how the stages of Kolb's model can be incorporated into the major design project and results presented in the paper.

76.1 Introduction

The design studio plays a crucial role in product design education because most students spend considerable time and effort learning in the design studio. Anthony [1] stated that the design studio provides students with their own space where they can draw, study, work, talk and even sleep. Therefore, the design studio has become the central learning environment for all design students in design schools. The most common module for teaching and learning at universities comprises lectures, assignments and examinations. However, teaching at the design studio is unique.

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Fig. 76.1 Major design project exhibition in 2015

The major design project (MAJ) involves sixteen weeks of teaching, followed by two weeks of design exhibition (Fig. 76.1) at one of the international universities in China campus. The students propose their chosen design topics first, which must be accepted by their lecturers based on the relevance of the topic to the module.

Various topic selections can lead to dissimilar design journeys. This module was taught for the first time in China campus in the 2015 spring semester. Students were asked to complete first a draft sketch and then present their final designs. Their presentations were marked by all product design staff, and oral and written feedback was provided to the students to help them to improve their final designs before the exhibition; most of the students used the feedback to refine their designs. The process of presenting work, receiving staff feedback, and revising designs is called critiquing [2], and it helped product design students gain design knowledge and experience from their lecturers. In general, most students achieved satisfactory outcomes and several students attained the first-class level. Figure 76.2 shows two good examples of students' design works, called Moving Design Studio and Invisible Studio.

After completing the teaching module, student evaluation of teaching (SET) and student evaluation of modules (SEM) surveys were obtained. After the first semester, students suggested that more critiques (feedback) help them to acquire design knowledge and manage their time more effectively. Although it increases staff's workload, all design lecturers agreed to provide more feedback and adopted the practice for the following year of MAJ teaching. Adding three more added critiques, which were delivered at different design stages, is shown in Table 76.1.

The student learning outcomes in 2016 were not as good as those of the preceding year, and none of the students achieved the first-class level. Therefore, there is a need to further improve this module, particularly because it is worth 60 credits and includes a public design exhibition. To address this issue, we propose Kolb's

Fig. 76.2 Good MAJ examples in 2015 (left: Moving Design Studio; right: Invisible Studio)

Table 76.1 Adding more design critiques for major design project 2016

Critiques	Design stages	Dates
1.	Topic selections—adding it in 2016	25 Feb 2016
2.	Sketching—adding it in 2016	17 Mar 2016
3.	Sketch model making	7 Apr 2016
4.	CAD modelling and engineering drawing—adding it in 2016	5 May 2016
5.	Final design	26 May 2016

[3] experiential learning cycle as a framework to develop assessment strategies for various design stages and we argue that assessment strategies designed based on this framework to enhance student learning outcomes. We illustrated how the stages of Kolb's model can be incorporated into the major design project.

76.2 Kolb's Experiential Learning Cycle (ELC) Model

76.2.1 Using Kolb's ELC to Improve Student Design Learning Outcomes

Learning is the process of creating knowledge through experience transformation [4]. In Kolb's ELC, learning takes place in four phases, as shown in Fig. 76.3 (next page). Kolb believes that in order to gain a complete learning experience, students must go through all four phases of the learning cycle. According to Kolb, these

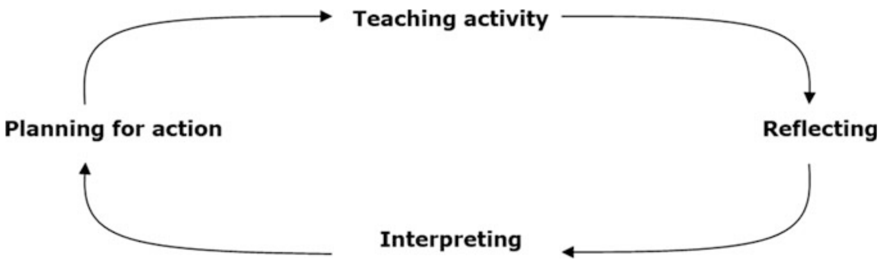

Fig. 76.3 Four stages of Kolb's experiential learning cycle. *Source* Kolb [3]

learning styles are the product of two pairs of variables, and they are *doing with watching, thinking and feeling*. Each phase of Kolb's ELC can be mapped to these variables. Everyone has a preferred learning style, but everyone will react to various learning styles to some extent and need stimulation [5]. Kolb's ELC offers the opportunity to complete each learning style, and a specific stage may match one's learning style preferences. Some of the criticisms of Kolb's model are that learning does not usually occur in consecutive, ordered steps, but that the steps overlap [6]. However, these criticisms are not sufficient to exclude the contributions from Kolb's model. Therefore, this paper adopted Kolb's model as a framework to enhance students' learning outcomes in the major design project.

The framework in this project contains four stages: reflecting, interpreting, planning for action and teaching activity. (1) Reflecting: review the experience from different perspectives, e.g. from own observations and based on feedback from others; (2) interpreting: form, reform and process ideas into logical theories, coming to an understanding. Relate the ideas to the wider context, e.g. existing literature; (3) planning for action: using the new formed ideas and theories to make decisions, problem-solving and plan subsequent teaching activities; (4) teaching activity: involvement in new experiences—the doing part. Teaching here embraces all aspects of teaching such as lecturing, supervision, tutoring small groups, assessing and module convening [7].

76.2.2 Reflecting

All teaching staff agreed that both the design process and design outcome learning are equally critical for the MAJ, because good design process produces great design outcomes. We taught the module twice, in the spring semesters of 2015 and 2016, although all teaching staff exerted great efforts to provide feedback for the five design stages of student presentations (Table 76.1), the student learning outcomes worsened in 2016, evidenced by no one achieving the professional (first-class) level.

The second-year learning outcomes of the MAJ indicated that the teaching method (more student work presentations) we applied in 2016 was problematic. After carefully reviewing each student's design process, we determined that over the course of the sixteen-week project (divided into five small design projects) students only had approximately three weeks between two design stages. Thus, although we provided more oral and written feedback, students did not have time to refine their designs and simply copied their draft sketches for the final designs.

The MAJ is a project-based module in the design studio for students' final semester study and is the final project of the Bachelor of Engineering degree programme. As noted earlier, this module comprises one project, which develops and later showcases the design skills of the students at the end-of-course exhibition. Through practical design work, the students grapple with the problems of managing various constraints and producing cohesive design proposals. Moreover, the project provides students with details about design solutions and the manufacturing of their product.

We collected student feedback through the 2015 and 2016 SET/SEM surveys and a series of interviews. Three students who had already graduated volunteered to participate in the interviews. Notably, we found some correlations in the SET/SEM responses; for example, both of the SET/SEM received a *neutral* score in 2015 and an *agree* score in 2016. As discussed earlier, the module requirements are very challenging for students because they need to (1) resolve complex problems as part of an open design brief, by employing the skills and knowledge they have gained from the programme; (2) demonstrate their ability to design a product, considering all aspects of its requirements in detail; (3) manage a complex and substantial design project over a lengthy period of time; and (4) present complex ideas, products and systems in an appropriate way, suitable for the target audience and correctly formatted.

Most students complained that they did not have enough experience to choose their design topics. Unlike other modules, lecturers provided the design briefs so that inappropriate topic selections resulted in less successful design outcomes and marks; however, even after selecting a suitable topic, students were still required to determine an appropriate solution using 3D forms to solve the problems they had defined in their research. Overall, students appeared to be unsatisfied with this learning experience. Additionally, based on SET/SEM comments from 2015, more design critiques during the design processes were encouraged. In response, we increased the number of design critiques from two (mid-review and final-review) to five and provided more staff feedback; on this portion, students' satisfaction levels increased slightly in 2016.

To further improve our teaching methods, four questions were asked during the interview.

Q1: Did you find that our teaching plan (research → sketching → sketch models → CAD modelling → prototype → poster → design report → final presentation → design exhibition) encouraged you to focus on the design process and to achieve superior design outcomes, or do you think students should choose their own ways to complete the projects because different design topics require different methods?

Students A and C stated that the strict teaching plan was appropriate and helped them to manage their time, whereas Student B suggested that it could be optional for students to choose their own methods. They all agreed that students with more design experience should be allowed to develop their own design processes, but that students with limited design experience should follow the assigned teaching plan. In addition, Student A provided some constructive comments for improving the design stages, especially in the early design phase:

> Before research, the students should define their own brief: what problem they want to solve? This problem should be better described in one sentence; a good topic should be brief and clear. (student A)

> Our research phase is lack of effective methodology. Some students did it too general (simply conduct on-line survey on the particular question they've already knew/expected the answer) some too specific without proper summary or categorise the user. (student A)

Q2: Did you find that meeting different tutors helped you receive more useful feedback on your design project, or would you have preferred the more traditional route of one supervisor who guides you throughout the design process?

All the students agreed that the feedback from various tutors was helpful. However, Student A also recommended that every student selects one tutor to be a primary supervisor, because too many directions from different tutors can sometimes be confusing. Student B thought that receiving several different suggestions from supervisors would help the students to develop their critical thinking skills:

> They should have the ability of analysing the feedbacks, pick up the useful suggestions. For the suggestions that they do not agree with, give the reasons. (student B)

Q3: Did you find that a formal review and mark at every design stage was useful in terms of time management, or would you have preferred a review and mark only at the final presentation stage?

All the students agreed that a mark at every stage was better and fairer. However, they also suggested that the proportion of marks should be adjusted for different design stages, with the final stage being worth the most marks.

> For an industrial designer in commercial world, design process (especially marketing research) is as important as the final result. A good research with accurate product positioning always leads to a good design solution. While 60% mark in the final stage ensures that students will always need to refine their design, to the end of project instead of making no improvement in the late stage. (student A)

The reflections from staff and student perspectives have been useful for identifying several areas that could be further improved. In particular, we discovered how various strategies for assessing the design stages may impact students' final design outcomes and their learning experiences.

76.2.3 Interpreting

In this section, we focus upon two aspects of my teaching plan that arose from the reflecting stage: the purposes of using different design media and applying strategies for design critiques.

First, we reviewed the relevant literature related to design to make sense of our reflections and to improve teaching quality. Contemporary design practice encompasses a range of visual representations, including sketches, CAD models, manually sketched models and physical models. Designers use these media for multiple purposes, such as to create artefacts that reduce cognitive load or as triggers that facilitate the communication of ideas and exploration of design problems. Romer et al. [8] found that the two most frequently used design media in both the design industry and design schools are sketching and CAD modelling. Sketches are ambiguous but allow designers to explore alternatives, while CAD models accurately specify the dimensions of objects and their relationships with each other. When Ibrahim and Rahimian [9] compared traditional sketching, CAD modelling and mixed media (combined sketching and CAD modelling) to assess their influence on design cognition and activities, they found that mixed media design environments improved the quality of the design process, as well as the quality of the ultimate product design. Based on these findings, we recommend that students adopt mixed media to generate their solutions and produce better outcomes; moreover, with this strategy, we will not need to ask students to complete individual sketching and CAD modelling presentations in the MAJ 2017.

A creative design process is optimally defined by its output; as scholars, and the interview results herein, have indicated creative design processes produce great design outcomes [10]. Teaching student's creative design processes is a common goal of most product design courses worldwide, and therefore, having a complete understanding of the processes that lead to creative designs is of great interest to academics, designers and design researchers. In earlier descriptions of creative engineering design, Buhl [11] described design as a linear sequence involving the following steps: (1) preparation, (2) synthesis, (3) analysis, (4) evaluation and (5) presentation. Similarly, Isaksen et al. [12] described the creative approach to problem-solving as a linear sequence of (1) framing a problem, (2) exploring data, (3) generating ideas, (4) developing solutions and (5) appraising tasks.

The development of creative design processes was traditionally viewed as a sequence of activities that began with the formulation of a problem, leading to the synthesis of solutions [13]. However, design problems are often ill-defined [14], meaning that there is no definitive formulation for the design outcomes. Thus, creative designers must constantly generate design alternatives to redefine uncertainties. In practice, a designer develops and redefines both the formulation of a problem and his or her ideas for solutions, iterating between the design processes and requirements until the final outcome is achieved. According to our discussion about students' learning experiences and the design critiques in 2016, students' design processes were linear, which results in less creative design outcomes. One strategy for adopting a suitable design critique to address this problem was encouraging students to consider our design feedback for refining their previous designs, because creative design requires fluctuation between design problems and solutions.

Research in cognitive psychology has revealed that uncertainty is central to solving complex problems [15]. Indeed, uncertainty is essential in the earliest stages of problem-solving because how a problem is initially discovered and structured is a vital precursor to its solution [16]. Design tasks are particularly concerned with ill-structured or wicked problems, because the solutions are unknown throughout the design process; thus, exploring different ideas under uncertain conditions is a natural occurrence and uncertainty becomes a tool to help a designer explore alternatives. During the early design stages, a designer also engages with the iterative design process of evaluation to gain valuable insights into the boundaries of the original problem [17]. This echoes Student A's response to the first interview question: '*…Some students did it too generally (simply conducted online survey on a particular question they already knew or expected the answer to)…*'. In short, the proper MAJ brief must contain some uncertainty to produce design alternatives; otherwise, students may merely reproduce one idea for their final designs. To avoid this situation, we would suggest that students present their potential topics during the first design review. Subsequently, all of the staff's oral and written feedback will be provided and, guided by that feedback, students can make informed choices of topics.

76.2.4 Planning for Action

In this section, we provide an overview of a refined MAJ teaching plan for use during the 2017 module based on a reflection of our experiences, the input from students and the ideas described in the literature. The aim of this project is to enhance students' design outcomes through suitable design critiques and marking criteria. Too many design critiques may deconstruct the major design project into several small design projects which curtail the students' time to consider our feedback. To provide more time for the students, the subsequent timetable identifies three possible design critiques: research insight and design thinking, 1:1 sketch modelling, and design outcome, and a timeline for their implementation (Table 76.2).

Table 76.2 Timetable of design critiques for MM3MAJ in 2017

Critiques	Design stages	Dates
1.	Research insight and design thinking	23 Feb 2017
2.	1:1 sketch model	6 Apr 2017
3.	Design outcome	18 May 2017

Table 76.3 Marking criteria for research insight and design thinking

Criteria	Research insight and design thinking	Percentages (%)
1.	Propose design problems	10
2.	Potential design solutions	10

In 2016, we found that giving students only a few weeks to complete their sketching presentations was insufficient. They were not connected to their topics, and many students eventually modified their topics or changed design directions. Based on the findings [17] and as discussed earlier, the creative design process must oscillate between the design problem and solution; in short, students need to present their topics and potential solutions at the same time (Table 76.3), a problem that requires more time to accurately flesh out. Using mixed media (both sketches and CAD models) [9] to develop the concept solutions is also recommended, because it has been demonstrated to help designers to achieve better design outcomes.

We also suggest adding a marking criterion for students who address staff's comments about refining their projects, because this is particularly beneficial (Table 76.4). All the staff agreed that 1:1 sketch models play a key role in product design because they enable users to test ergonomics and confirm working principles before mass production.

As suggested by Student A, we propose that the design outcome presentation weigh 60% of the total 60-credit module mark (Table 76.5), which reflects the assumption that students do and should expend more effort on their final design. Novel ideas implemented throughout the designing process are encouraged; however, the students must also prove that the final design fully and appropriately solves the topic.

Table 76.4 Marking criteria for 1:1 sketch model

Criteria	1:1 Sketch model	Percentages (%)
1.	Address staff's comments by refining and improving previous designs	10
2.	Solve problem using 3D physical models	10

Table 76.5 Marking criteria for the design outcome

Criteria	Design outcome	Percentages (%)
1.	Address staff's comments by refining and improving previous designs	10
2.	CAD model rendering	10
3.	Manufacture details	10
4.	Design creativity	10
5.	Poster design for exhibition	10
6.	Design report	10

Table 76.6 Three-year student learning outcomes

	2015	2016	2017
Student no.	20	17	25
Average mark	64	59	63
Standard deviation	7.2	9.8	12.1
No. of first class	4	n/a	3

76.3 Results of Teaching Activity and Conclusions

We were excited to present a refined teaching plan for MAJ and were confident that it facilitated a superior learning experience and improved design outcomes from students' learning (Table 76.6). Three MAJ students reached the first class design outcomes in 2017. Their project topics are called GreenBox, Fidget Pen and OneWork. This framework proved that Kolb's experiential learning cycle is useful to enhance students' learning outcomes for the major design project because students can focus on potential design topics and have enough time to refine their final designs based on staff feedback. The different design tools such as sketching or CAD modelling can use at any time as long as they can progress their design processes. The ethical application of the project has been approved by the university research group.

76.4 Acknowledgements

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Chapter 77
Role of Short-Term Intensive Activity as a Precursor to Design Conceptualization

Manasi Kanetkar

Abstract 'Design links innovation, technology, research, business and customers to provide new value and competitive advantage across economic, social and environmental spheres'—the definition of design by the World Design Organization (2015). It also redefined the varying roles a designer needs to assume. On the other hand, many industries are working on an acute specialization in technological fields or expertise in which they are operating. Design has also shown such possibilities, e.g., human factors, packaging design. In response to the extremes, specialization and generalization, design education needs to change. The educational programs also need to address the need of a designer to quickly learn the intricacies of a new domain. Today a design student learns a variety of subjects seemingly unrelated to each other. Each subject demands an attitudinal change from the students. This paper presents two case studies of short-term intensive activities (STIA) which are introductory exercises in the form of contextual short-term goals.

77.1 Introduction

Industrial design as a profession has been evolving. Although it started as a bridge between industrial manufacturing and traditional crafts; it has come a long way from there.

Findeli [1] mentions that though various models are available for teaching visual intelligence, designer is more than a 'rational computer.' While proposing solutions, we have to usually deal with systems and complex sub-systems. He also argues that the role of an industrial designer is changing by the virtue of 'vanishing product.' Findeli suggests that we endeavor to construct our basic design in form of 'spiritual exercises' the nature and context of which would be adapted to our contemporary world and future challenges.

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‘One of the essential difficulties and fascinations of designing is the to embrace so many different kinds of thoughts and knowledge’—mentions Bryan Lawson in his book called ‘How designers think: The design process demystified (2005).’ This changing definition of design and evolving design practice make it evident that design education also needs to respond the change.

Students need to make a ‘cognitive switch’ between two different subjects of interest. A verbal instruction or the most effective audio–visual presentations may fail to help them make this switch. Thus, a technique with quick exercises that had very specific and contextual goals was tried. The exercises demand active participation and complete attention.

George Brown and Madeleine Atkins discuss methods of teaching in their book called effective teaching in higher education (1988). They mention that there are two extremes; one is the lecture in which student control and participation is usually minimal, the other is private study in which lecturer control and participation is usually minimal. A methodology which enables active participation from the teacher as well as the students could be more effective to get the students’ focus and attention drawn to the contents of the course.

This paper documents two of such short-term intensive activities (STIA) conducted with the students. In both these exercises, goals chosen were specific to the subject matter. The time span given was one working day. The focus was defined clearly though the end result was open-ended.

77.2 Substantiation

In an earlier study of design teachers, Drew (2000) five qualitatively different conceptions of design teaching are described.

Fischer and Herr [2] propose a generative system to be used in the design process, which responds to various social- and industry-specific contexts. Generative system is a setup based on abstract definitions of possible design variables; the paper proposes pedagogical suggestion as early steps toward changes design teaching.

The abovementioned experiments stress that design education needs to evolve and respond to the changing times. The educators need to employ new approaches and tools to ensure that the students’ experience of learning is enriched, breaking as many barriers as possible, and the learning is retained well.

77.2.1 Objective Understanding

Each subject that a part of design education; demands objective understanding. For example, in ergonomics, the most important aspect that needs to be is ‘to create a product comfortable for maximum cross section of the population by addressing to the extremes.' In spite of various implications and finer aspects, the underlying principle remains the same.

In case of interface design, it is of utmost importance to convert 'intangible entities to tangible ones.'

77.2.2 Clarity and of Goal

The design process is usually complex; built on multidisciplinary tests for the solution that works on all the fronts, so that it is implemented. While achieving this, students tend to lose the objectives of the course. Thus, STIA[1] usually with the time line of one day was planned for each course. The clarity of goal, time crunch for STIA helps the students to find a focus.

77.2.3 Sense of Achievement

At the end of the day, the students have a tangible output and they can feel proud about the same. Students, persuading undergraduate programs especially in India, have minimal or no exposure of creative exercises as core curriculum. Foundation of design consists of assignments that are focused on learning a single aspect of art or design. Thus, while perusing projects, it is difficult for them to start working toward a long-term goal. This sense of everyday achievements helps them.

77.2.4 Stimulation

Students tend to display a lot of energy in short-duration exercises. They are also open to experiment; are willing to team up with lesser-known colleagues. Seamon [3] proposed that 'students in the intensive version of the course performed significantly better than students in the semester-length course,' he also states that the performance was dependent on no other factor but only on the intensiveness.

77.2.5 Disruption and Unlearning

Human beings have a natural habit of economizing the work that forces us to be complacent and unwilling to change. The STIA should be disruptive in nature,

[1] *STIA*—short-term intensive activity, hereon referred to as STIA in the paper.

so that it helps break any link with the previous courses the students have learned. The thought process tends to be carried from the earlier method of information processing and/or the working methodology. The STIA planned should have a 'fun' quotient to it, to draw the students' attention.

STIA activity carries less or no part of the credits; since the number of hours spent on the activity is very limited. Thus, students work on the assignments without worrying about the final output and its effects in their 'report cards.'

77.3 Case Study 1: Super Special for Ergonomics

77.3.1 Trigger

Ergonomics is an objective method of evaluation. It also involves understating of anthropometry and requirements for extremes and special needs to address maximum cross section of users. It was noticed that the students were finding the subject uninteresting and completed the assignments without involvement.

A joke on Ravana (10 headed demon from Indian mythology Ramayana) mentioning that he couldn't wear a T-shirt triggered a thought that the superheroes or characters from mythology, fantasy novels or movies could be studied. The study of 'super-special' characters was considered as an opportunity against the study of special needs.

77.3.2 Method

STIA was planned for a quick introduction of ergonomics. The goal of ergonomics is to make the products/environment safe, comfortable, intuitive and lastly 'inclusive.' In order to appreciate the last aspect, students were asked to design products and/or spaces for superheroes, which are *differently-abled* so that they fit in the common human environments.

The students were divided into groups of 4 or 5. Each group selected a 'super-specially abled' character to begin with. They were asked to understand interactions between superheroes with human spaces both private and public. Each group identified 8–10 issues that the character would face. Solutions were proposed for the problems that could be solved through design.

77.3.3 Results

Empathizing with 'one' character was much easier than with a cross section of the population. There were ten teams, each studying a different character. Variety of

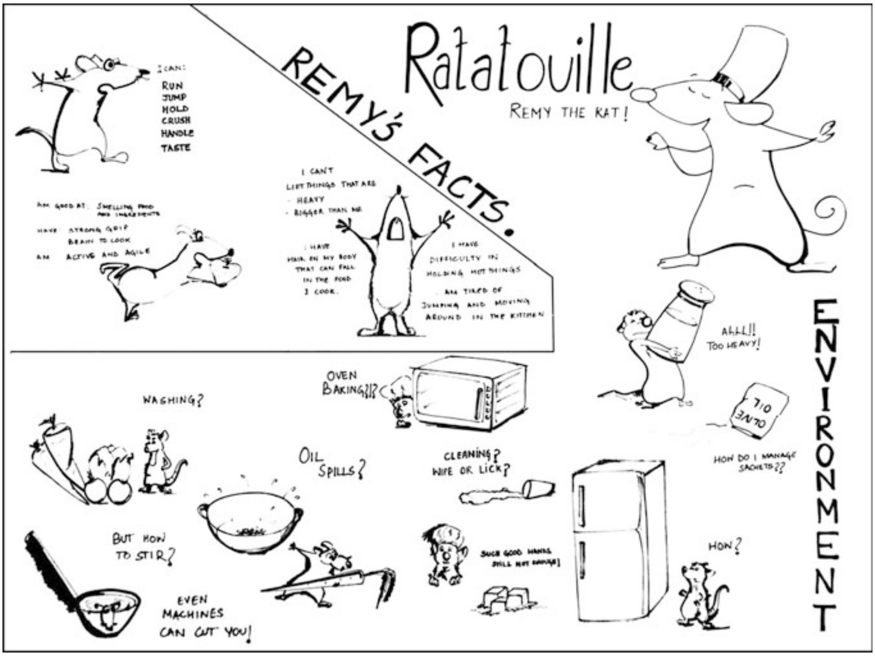

Fig. 77.1 'Super-special' issues: a rat in human space

ergonomic problems that can occur due to extreme physiologies were brought to the table by all the teams. The physical features and anatomy of all the characters that were chosen were very drastically different from a typical human anatomy. Breaking away from the clinical understating of anthropometry also resulted in better enquiries in ergonomics.

The interactions and visualization of the same were clear to the students, since the characters were very familiar. Students were very proud as well to be associated with 'special' characters and exhibited energetic behavior.

Figure 77.1 shows problems identified for Remy, from a 2007 American computer-animated comedy film 'Ratatouille' produced by Pixar and released by Buena Vista Pictures Distribution. 'Remy' is a rat who cooks in a human kitchen space. The benefits and hazards that Remy may face based on the physiology were critically analyzed. In the animated movie Ratatouille, the rat was shown to have agility, but obviously found it difficult to manage weights and hazards from heat and sharp kitchen tools.

Figure 77.2 shows the solutions were proposed. They included mechanical devices like levers for spoons and ladles; a pulley and a ladder for the rat to work around big utensils; and a monowheel as a pizza cutter.

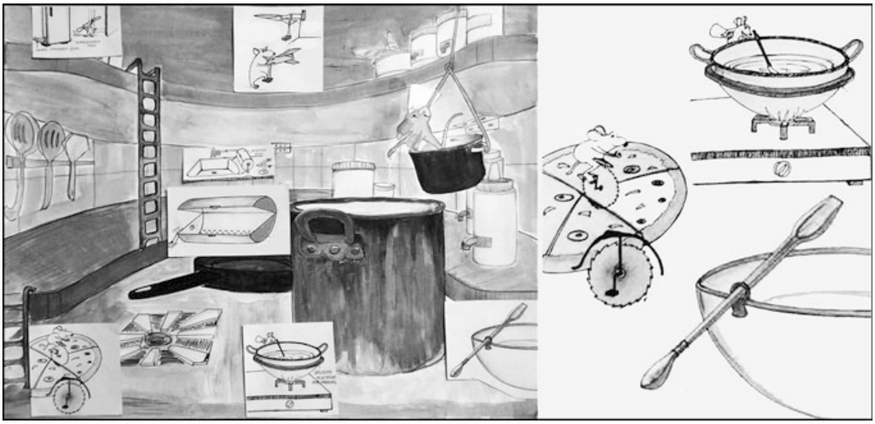

Fig. 77.2 ‘Super special’ solutions: a rat in human space

77.4 Case Study 2: Intangibles for ‘Human Machine Interface’

77.4.1 Trigger

The definition of a product has changed over the last decade. It is not bound by the physicality that it has. A product communicates signs, interacts with you and influences lives. A product is a part of an ‘experience.’

Experiences are intangible/unquantifiable therefore complex to understand. The students need to break the experience in actions and microactions, without losing the essence. A tangible product/signal can be used to make a particular action easy to comprehend. A proposal that integrates these actions and corresponding tangible entities is a fulfilling experience.

In order to simplify the task, abstract ideas of singular nature or meaning were chosen. This STIA helped them break experiences in smaller intangible factors.

77.4.2 Method

The STIA for human interaction was ‘intangible to tangible,’ was a daylong activity.

The students worked in groups of four. They were asked to choose an intangible/ abstract concept.

1. An idiom/proverb
2. A philosophical concept
3. Scientific phenomenon

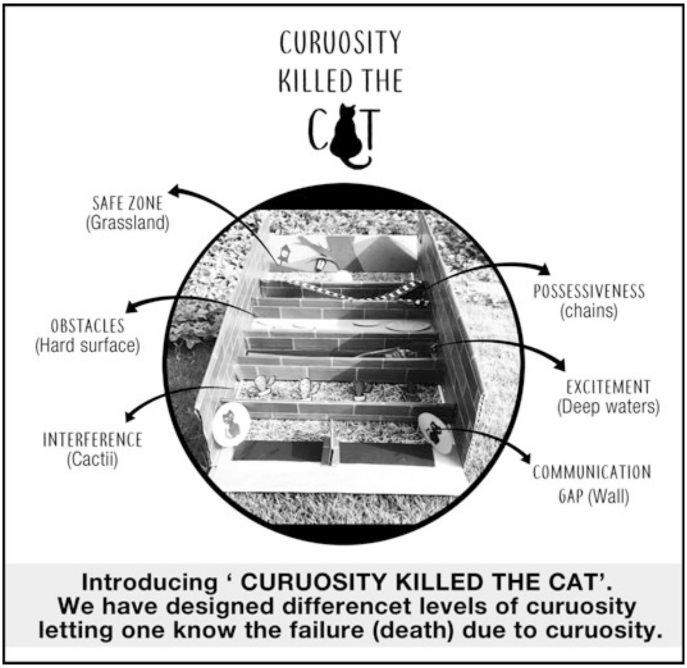

Fig. 77.3 'Representation of curiosity killed the cat'

The concepts then were then converted to tangible entities by using 'quantification' and 'multiple sensory signals.' The task was to keep the meaning intact and bringing it out to an environment/product.

77.4.3 Results

One of the teams chose the proverb 'curiosity killed the cat.'[2] The dictionary meaning of the proverb is 'being inquisitive about other people's affairs may get you into trouble.' The meaning was evaluated and situations where curiosity is not justified were listed down. Then it was given physicality as a game to pass a ball through a hole.

When one plays the game, the target is very difficult to achieve; the ball falls into various levels of misconduct/misfortune. They are extreme excitement, possessiveness, restrictions and communication gap. Figure 77.3 shows a paperboard mock-up, made by the students at the end of the day.

[2]https://idioms.thefreedictionary.com/curiosity+killed+the+cat (visited on 21/09/2018—10:28 AM (UTC+05:30)).

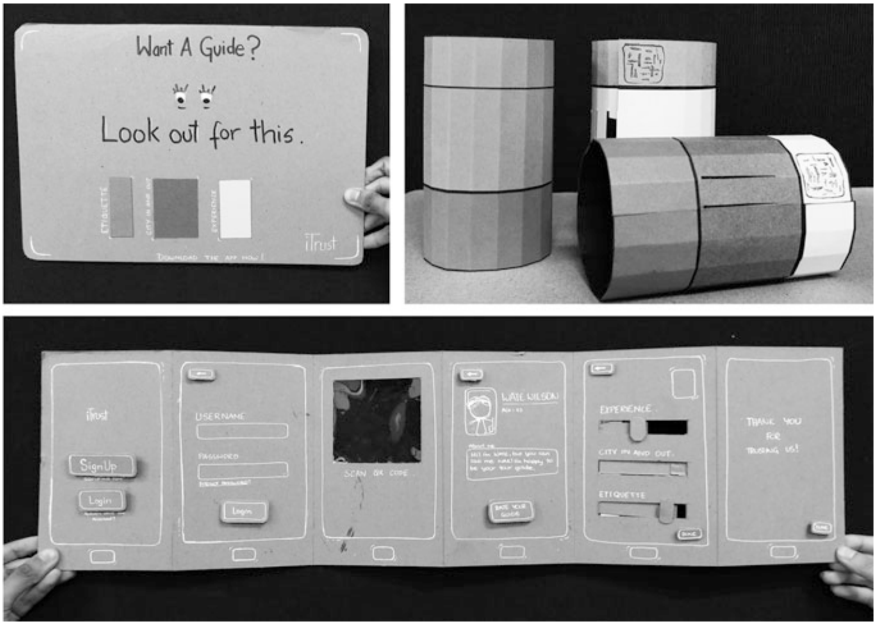

Fig. 77.4 Paper mock-up of i-trust' hoarding, band and mobile phone application

Each level of the game has been symbolized by various environments; namely cacti, deep water, extreme hard surface and chains which mapped with the misfortunes mentioned above. The overall meaning of the proverb was depicted very well.

Another group chose to represent 'trust.' They further analyzed the contexts where trust is crucial. Out of a few listed down, they chose tourism as their context and 'trust in tour guide' as an issue. They proposed a hand band 'i-trust' as a wearable product for the tour guide to represent 'trust.' The factors of trust were stipulated as 'experience,' 'city in and out' (does he have peripheral knowledge about the city?) and 'etiquette.'

Each of the factors is a part of the band; can change the color depending on the ratings by the tourists. The rating and more information could be obtained through a quick response system (QR); code printed on the band. Mobile phone application screens were also simulated.

The concept of 'trust' was very well addressed to, leaving aside the technical and practical constraints of the system. Figure 77.4 shows the quick mock-up of 'i-trust'.

77.5 Discussion and Conclusion

77.5.1 Challenges

STIA has been a methodology; it has been practiced for the last four years. Each subject or course is based on certain set of criteria and demands an attitude of its own. Breaking the goals and learning objectives into smaller tasks and still retaining the essence of the comprehensive course learning has been a challenge. It is also a challenge to keep the students' focus on a particular aspect of design.

The response from students has not always been the same. The energy and the response level to the STIA are overshadowed by the previous activities.

A few times the opposite has been observed. Some groups tend to get thrilled with the fun quotient and deviate from the goal. They require constant supervision and guidance in the correct direction. It becomes difficult to achieve desired results; while handling the large number of students, in a short time frame.

The activities are planned in response to short time frames. The students go through a rigorous activity, need to come up with solution, and represent them in the time frame of one day. The students go through an intensive cycle of analysis, planning and execution. The evaluation by the faculty has to be in accordance with the same, and the feedback needs to stress the objective of the course.

77.5.2 Applications of STIA

The STIA tool has been implemented for various other design courses namely packaging design, human machine interface and nature inspired design.

Each significant course can become more effective with STIA, in understanding and retaining the learning from the course.

In future, STIA tool can be defined in a more structured manner, along with the guidelines for defining key learning, defining outcome etc.

77.5.3 Making Memories

A well-defined short-term goal has clarity. The fact that it can be a 'sprint' makes it exciting and brings out the competitive spirit in students. It has been observed that the retention of memory for activities that are rigorous and are exciting for students is much greater than that of the long-term projects.

On the other hand, a design project has multiple stages, some of them requiring students to internalize issues and/or design aspect and then realize a solution. This process also relies on intuitive learning that is difficult to quantify.

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Chapter 78
Teaching Design for Sustainability for Socioeconomic Ecosystems—Three Case Studies

Sharmistha Banerjee, Pankaj Upadhyay and Ravi Mokashi Punekar

Abstract This paper presents our teaching method and insights gained through conducting a course on system design for sustainability for undergraduate, postgraduate, and doctoral students with an intervention focus on socioeconomic ecosystems (SEEs): A context where the economic activities of the community are deeply ingrained in the sociocultural ways of living is a multi-stakeholder ecosystem, and the economic activities are distributed in nature. The key issue tackled in the teaching strategy is: How to understand and explore sustainable socio-ethical orientating of a SEE in the Indian context? The objectives of the course are: introduce design for sustainability (DfS) in a global context and SEE in Indian context; investigate sustainability in a scenario which is abundant with years of tested methods of living in harmony with nature and themselves; identify new challenges entering the system and its impact on sustainability; and ideate socio-culturally apt sustainable PSS. Our key finding, sustainability, as a concept, is complex for students at all levels, and they find difficulty in conceptualizing systems where sustainability is in economic advantage of the stakeholders. We observe an overall improvement in systems thinking, interdisciplinary approach, and anticipatory competence of students. The paper concludes with recommendations and strategies for enriching and restructuring a DfS course.

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78.1 Introduction

The past two decades has seen a rise in the research and practice of higher education for sustainable development in higher education institutions all across the globe. Several types of curricular development have happened across disciplines. These curricular developments have either laid their focus on the development of one course or weaving the fabric of sustainability across the entire program [1]. Two approaches can be used to implement sustainability in the Design school curricula: (1) Sustainability is looked upon as one of the criteria within the frame of reference of current design activities and priorities (sustainability in the design context); (2) design is looked as a dimension of sustainability framework (design in the sustainability context). In our context, the course on system design for sustainability (S.DfS) can be seen as a one-of-course in the design curricula where we teach about sustainability. But within the course, we adopt the second approach, i.e., design in the sustainability context. The course is offered as an elective to the final year undergraduate and postgraduate students. The course is also open to doctoral students, but the content is tailored to suit the needs and levels of expertise and knowledge of the previous group.

A literature review reveals four types of DfS approaches: product innovation level, product-service system (PSS) innovation level, spatio-social innovation level, and socio-technical system innovation level [2]. The literature on pedagogy design on the first type abounds while that on the second type are also present to a certain extent mostly in the context where a company/promoter wants to offer sustainable PSS (S.PSS) solutions, including S.PSS for base of the pyramid [3]. Case studies of the third type and fourth type exist with little pedagogy-oriented literature. The focus of our paper is ecosystems wherein the economic activities of the community are deeply ingrained in the sociocultural ways of living. These contexts are common in India in sectors like craft, handloom, and tourism. Not much literature is available on pedagogy in the area of DfS for these contexts. Thus, the aim of the paper is to explore pedagogy in this scenario.

78.1.1 Defining Socioeconomic Ecosystems (SEEs)

A SEE is a context where the economic activities of the community are deeply ingrained in the sociocultural ways of living. For example, our first case study from Bordowa is a local tourist spot since it is the birthplace of saint Sankardeva who is the founder of Vaishnavism in this region. It is visited by lakhs of people. The socioeconomic fabric of Bordowa is deeply influenced by the teachings of the saint (refer 3.1). In these contexts, the major challenge for DfS is: How through design, one can bring about: first, the sustainability orientation to the socio-ethical dimension in a manner that it is in the economic interest of the system stakeholders to be so and, then, the sustainability orientation to the environmental dimension in a manner that it is in the economic interest of the system stakeholders. Another characteristic of these contexts is it is difficult to identify one company or stakeholder who is the promoter or provider of the offerings of the SEE. Instead, these are multi-stakeholder ecosystem. The inherent nature of the economic activities in these contexts is distributed (distributed economy) in nature. SEE might be distributed in terms of design, manufacturing, and knowledge generation. These ecosystems might also have a long history of existence and as a result evolved their system to be sustainable on many accounts. In order to initiate any design intervention, thus, a designer must deeply study these traditional ecological and social knowledge systems and their integration with the local cultures.

This paper presents a strategy for teaching DfS for SEE with a S.PSS approach. The key issue tackled in the presented teaching strategy is: How to understand and explore sustainable socio-ethical orientating of a SEE in Indian context?

78.2 Developing the Pedagogy

A literature review reveals an extensive discussion on pedagogical approaches and the competences to be delivered to students so as to train them in the domain of DfS [4]. Rodrigo et al. conducted a thorough review of research in this area and devised a framework connecting pedagogical approaches and competences delivered. The twelve competences for synthesis of Education for Sustainable Development (ESD), used in this framework, are: (1) systems thinking; (2) interdisciplinary work; (3) anticipatory thinking; (4) justice, responsibility, and ethics; (5) critical thinking and analysis; (6) interpersonal relations and collaboration; (7) empathy and change of perspective; (8) communication and use of media; (9) strategic action; (10) personal involvement; (11) assessment and evaluation; (12) tolerance for ambiguity and uncertainty. The twelve pedagogical approaches used are classified as: universal (case studies, interdisciplinary team teaching, lecturing, mind and concept maps, and project and/or problem-based learning); community and social justice (community service learning, jigsaw/interlinked teams, participatory action research); environmental education (eco-justice and community, place-based environmental education, supply chain/life cycle assessment (LCA), and traditional ecological knowledge).

In our course design, we used all the pedagogy approaches classified under universal as they have the capability to contribute toward the twelve intended competences to different extents. Since a focus was onto SEE, we also used the pedagogy approach—participatory design (PD). A module on LCA is built on competences (1), (2), (3), and (11). Since most often in the context of SEEs, a long history of existence resulting into inherent social, ecological, and economic sustainability exists, we see the benefit of including traditional ecological knowledge pedagogy approach to bring in the competences (1), (3), (4), (5), and (7). In our approach, we could not focus much on the competence (4) due to lack of teaching staff's expertise in that area.

As per a study conducted by Rieckmann [5], wherein 70 experts from Europe and Latin America ranked ESD objectives and key competences, differences were observed between respondents depending on if they belonged to the north or the south. For example, the European group gave higher importance to "transferring knowledge and understanding" while the Latin-Americans on "developing competencies." Overall, by all experts, the most important key competencies identified were systemic thinking and handling of complexity, anticipatory thinking, and critical thinking. This might be related to the differences in the sociocultural, economic, and political variations of the specific contexts of the countries in which the experts operate as teachers and researchers. This indicates that universities have to create unique learning settings, suitable to their own sociocultural, economic, and political contexts, which can impart competencies to students so that they can deal with them uniquely. All experts viewed that ESD is one of the central instruments for moving the society toward SD. Thus, "creating and changing values, attitudes, and awareness" and "developing competencies" were regarded as the most important objectives of ESD.

The objectives of our course are: "developing competencies," "creating and changing values, attitudes, and awareness," "transferring knowledge and understanding," "promoting sustainable behavior and responsible action," and "more just and sustainable society." We thus identified the following rank order for the key competences to be delivered. The ranking was done on the basis of our experience and understanding of the SEE context taken in our course. Three faculty members, involved in conducting the course, mutually agreed upon these rankings. The rankings are presented in Table 78.1 with the pedagogic approaches taken.

78.2.1 Step-by-Step Course Plan

Most of the students had experience designing products and services for individual consumption but not for community-based consumption. They were exposed to ego-centric design methods but had no exposure to PD. A rural location was selected as most students did not have a rural background and had not explored design for rural way of consumption and satisfaction. About 68% of Indian population lives in rural areas, and hence, it should get its due share of design attention.

The objectives of the course were: (1) introduce students to the history, development, approaches, and tools for DfS in a global context; (2) understand a SEE in the Indian context and question how to tackle sustainability; (3) identify how indigenous systems have evolved to live in harmony and mutually symbiotic relationship; (4) identify what are the new challenges entering the system and how are they challenging the sustainability (social, environmental, and economic) of the

Table 78.1 Rank order for the key competences to be delivered in the course

Rank	Competences	Pedagogic approach
1	Systems thinking	Case study, lecturing, mind, and concept maps, problem-based learning, LCA, traditional knowledge mining
2	Interdisciplinary work	Lecturing by teachers from design, engineering, social sciences
3	Critical thinking and analysis	Using tools like MSDS, LCA, and case study
4	Anticipatory thinking	Using tools like MSDS and LCA
5	Interpersonal relations and collaboration	PD, lecturing by local stakeholders
6	Empathy and change of perspective	PD
7	Strategic action	Using MSDS tool
8	Tolerance for ambiguity and uncertainty	PD
9	Personal involvement	PD
10	Assessment and evaluation	MSDS and LCA tools
11	Communication and use of media	Presenting and validating ideas with stakeholders
12	Justice, responsibility, and ethics	PD

system. The students go through a systematic analytical journey which helps them in identifying the key stakeholders, along with the role, challenges, and expected gains for each of them. They analyze the indigenous systems using *Strategic Analysis Toolkit* (SAT) developed by the faculty team, system design models, MSDS [6], LCA and ideate on new S.PSS models which are culturally and socially apt for the given situation.

In order to have a dedicated time for the field trip, the course is organized in weekly modules wherein the entire week is dedicated to this course only (different from the IIT system where an hour/week system is followed). The first week of the course, where the theoretical understanding of sustainability, SD, DfS, and tools, is given, is conducted in January. The students are then divided into thematic groups and asked to conduct a literature research on the assigned area. We then meet again in the second and third week of February and introduce the case study through lectures by local stakeholders, visionaries, and administrators along with faculty and researchers from design, engineering, and social sciences. The students, then, make their field visits and investigate the subject using SAT elaborated in 2.2 and MSDS tools. Next, we meet in the first and second week of March to complete the analysis, PD, and evaluation.

78.2.2 Strategic Analysis Toolkit (SAT) to Study a SEE

The strategic analysis described in Table 78.2 is a substitute of the strategic analysis from MSDS tool (read [6, pp. 92–97]). The MSDS tool has been designed for a context when a promoter/provider can be identified who wants to offer a S.PSS. In the context of SEE, we have a multi-stakeholder ecosystem. Also, the need for S. PSS might not come from the ecosystem and can be initiated by the designer or a local administrator or a visionary. Hence, the foremost task in such cases is identification of actors and aspects of their activities. In order to achieve this initial identification in a short time and with visiting the least number of people, we do the identification by asking questions to local administrators/local visionaries. They are also a good source of information since they have an overview of the context and most likely a good knowledge of the problems. They might also have interesting contextually appropriate design directions to contribute to the team. Next, we identify from them the infrastructure, both existing and proposed. Next, we do a need analysis of each identified actor by speaking to the actors. Findings from these

Table 78.2 Strategic analysis to study SEE

Process	Sub-process	Result
1. Project socioeconomic ecosystem analysis	Preparatory questionnaire	Actor and their activity identification
	Infrastructure analysis	Existing infrastructure and transformation identification
	Actor analysis	Need analysis of the actors
2. Defining intervention context	Clarifying design goals	Problem statement, design brief, unit of satisfaction
	Competitor analysis	Competition space knowledge
3. System carrying structure analysis[a]	General macro-trends analysis	Report on (social, economic, and technological) macro-trends and their influence on the reference context
4. Analysis of cases of excellence for sustainability[a]	Identification and analysis of cases of excellence	Summary of cases of excellence analysis describing • Offer composition and interaction with the user • Actors who produce and deliver the offer • Sustainability characteristics
5. Analyze sustainability and determine priorities for design intervention in view of sustainability[a]	Existing context analysis (environmental, socio-ethical, and economic)	Summary of the existing system analysis
	Defining the design priorities	Definition of design priorities for each dimension of sustainability

Process 1 and 2 developed by us, 3–5 from MSDS tools
[a]Marked are from MSDS

three sub-processes are analyzed using SWOT, PESTLE, and Systems Map. Next, we define the intervention context using a PD approach with the actors. In light of the identified prospective design interventions, we identify competition space. Thereafter, we continue with the MSDS tools as listed in Table 78.2. Due to the limitation of space, the tools designed in each of the steps are not included here. To know more about the tools, read https://goo.gl/R7qmtD.

78.3 The Three Instances of Conducting the Course

The course was conducted ones at Bordowa (January–April 2015) and twice at Sualkuchi (January–April 2017 and 2018).

Bordowa. Bordowa is a village in Nagaon district of Assam, India [7]. Bordowa is the birthplace of Sankardeva (1449–1568), a great artist, dramatist, and the founder of Vaishnavism in Assam. It is located 140 km from Guwahati, the largest urban area in Northeast India, and is 18 km from the town of Nagaon [8]. The religion propagated by Sankardeva was characterized by simplicity and openness with no rules or restraints, in contrast to its contemporaries. The only requirement was love and devotion toward God. The religion has lived over five centuries through chanting of God's holy names and theatrical performances called bhāona. This village is a local tourist spot and attracts lakhs of tourists during the weeklong celebrations of Holi and Janmashtami. During rest of the year, a moderate number of visitors visit the place. This place has a degree college, one higher secondary school, one girls high school, a mini-health center, a library, a police station, a tourist lodge with six rooms, and a museum. There are no restaurants here. The place is also marked with a beautiful and clean lake called Akashi Ganga. No one pollutes the lake or harms the fish in the lake as it is considered pious. Farming is one of the chief economic activities of the residents of the village. Other economic activities are around the tourist industry, like making and selling Kuhila crafts [9], bamboo products, and public transport services. Most houses here have two ponds, one to grow fish for self-consumption and second for the household organic waste. This gets composted and is then used in their homestead garden to grow vegetables for their year-round consumption. Most houses also have a handloom machine where the women of the family still follow the tradition of weaving clothes for their household consumption. Analysis of socioeconomic aspects of conducting life here helped us to understand the underlying sustainability of the various practices in the village. Also, the traditions and stories which helped in marketing and maintaining these practices over generations were identified. Next, how the introduction of contemporary consumption and production is creating unsustainable living became our concern. For example, we noticed that the village does not have any facility to dispose of or collect plastic waste. Since wrappers of products like biscuits and shampoo are the new add-ons to the way of living here, the residents did not know how to deal with them. They were being either dumped in the ponds where they throw organic waste or burnt.

The students were divided into ten contextually relevant sub-systems: habitat, agriculture, small-scale industries, and rural-based economic activities other than agriculture, tourism, fisheries, health, education, water, sanitation, and transport. The main instructors of the course had expertise in the area of product and system design while the co-instructors had experience in green architecture, environmental engineering, economics, civil services, and sociology (local college professor acted as local guide). The priests, museum curator, and the trustees of the satra were also involved in providing information and getting us introduced to the local community. A NGO working in the sector of computer literacy helped us get introduced to the Muslim community living here. To get a glimpse of Bordowa, visit https://goo.gl/GvjZLT.

Sualkuchi. Sualkuchi, a census town in Kamrup district of Assam, consists of 16 villages. It is situated on the north bank of the river Brahmaputra, about 35 km from Guwahati. With a population of more than a lakh, this block is well known for its cottage industry and silk weaving and is called the "Manchester of Assam." It also has a trademark, Sualkuchi's, registered to Sualkuchi Tat Silpa Unnayan Samity. [10] The industry dates back its origin to debatable historical times with mentions in works of Kautilya who lived from 371 to 283 BC. The industry as we know today started flourishing under the patronage of the Ahom Kings (1228–1828 AD). [11] Since 1951, the growth in this industry has been rapid, reaching its peak, 500%, during 1981–2001 when the average looms per household increased from 2 to 6. During this time, many households also shifted to being entrepreneurs, hosting 50 or more looms and using employed weavers to weave rather than the yesteryears weaving enterprise run by family members. The place is known for weaving three types of silk, muga, mulberry, and tasar. The most commonly woven item is a Mekhela Chadar, a traditional Assamese dress. No wedding in this state happens without the bride wearing a Muga Mekhela Chadar. Other items made, in way much lower volume, are sarees, *thaan,* and Khasi dress (traditional dress of the Khasi tribe from the neighboring state of Meghalaya). There are four categories of workers: owners, weavers, reelers, and helpers. The owners might be small with less than 5 looms and big with more than 50 looms. They own the instruments of production, the Jacquard loom. In the case of small owners, they engage in weaving themselves with their family while bigger owners usually hire weavers. The weavers are contractual employees and are paid on the basis of length of garment woven and the number of design elements present. The weavers are mostly trained on the job. The reelers are engaged in pre-loom activities like reeling and spinning of yarn. They are paid on a contractual basis as well. Helpers are the lowest paid people, paid on a monthly basis, and help the weavers and owners in various activities. The major problems of the industry are: obsolete technology, unorganized production system, low productivity, inadequate working capital, conventional product range, weak marketing link, overall stagnation of production and sales, competition from the power loom and mill sectors [12], rising cost of raw materials [11] and adulteration and fake replicas spoiling the brand image. To get a glimpse of Sualkuchi, visit https://goo.gl/sLxNtS.

The students were divided into five thematic teams focusing on the production of silk cocoon, processing of cocoon to fiber, production of silk garments, selling value chain (local, global), and other services including testing, certification, branding, innovations, and financing. For the second academic year, the course was conducted by three faculties from IIT Guwahati with expertise in product and system design. For the third academic year, the course was conducted under the banner of LeNS India pilot course 2 wherein faculty from five national and international universities participated as teachers and students joined (design, fashion technology, architecture) from five different universities of India. The core instructors had expertise in product design, system design, S.PSS design, life cycle design, and architecture. The co-instructors for both years were local college professors from economics and fashion technology, local entrepreneurs, innovators, weavers, and district-level civil servants.

78.4 Learning from Conducting the Course

The course introduced the students to the amazing and inspirational way of conducting life in rural areas. According to the students, many of their preconceived and quite often negative notions of living in village and associated drudgeries are thwarted. The contextual and frugal innovations by farmers, local artists, and weavers amused them. The consumption and satisfaction system practiced by the villagers were at times new and totally alien to what the students had been exposed to before this. As a result, at times, it was also very difficult to understand it. Constant debates among themselves and discussions with the local experts helped in widening the students understanding of consumption and satisfaction. They started appreciating grassroots innovations, living with low resources, and the importance of systems thinking. They also started appreciating the traditional practices which have sustainability potential. We observed an improvement in students' competence in systems thinking, interdisciplinary approach, and anticipatory thinking. From an analysis of the reviews received by the participating students and faculty members and performance of students in written exam, where they were supposed to apply the concepts to new problem contexts, we gathered the following insights:

Sustainability—A complex concept. It is observed that sustainability, as a concept, is complex for students at all levels. Also, they find difficulty in conceptualizing systems where sustainability is in economic advantage of the stakeholders. They usually conceptualized S.PSS which needs to be funded or adhered to on sustainability principles by virtue of goodwill and charity. We had to constantly, with examples, point out that one can redesign the system wherein it is in economic advantage of stakeholders to be socio-ethically and environmentally sustainable. Post the course, students questioned the instructors: *Why have we not been taught to design this way in the beginning as this seems to be a more holistic design approach?*

Systems Thinking—A challenge for students. It was little difficult for the students to start thinking in systems (in spite of the fact that they had already done a course on system design) and anticipate its implications on sustainability at the same time. A lot of one-to-one group discussions were done to orient their concepts toward systemic thinking and sustainability. Both the systems, studied under the course, seemed too huge for the students to be able to tackle in the five weeks of course duration.

Strategic Action. We observed that students experienced and learnt from the context, but while conceptualizing, the connect was lost. Thus, some of the concepts generated by the students were too generic in nature and did not carry in them the local flavor. The argument by various researchers that designers tend to make superficial, out of context S.PSS design solutions [2], is visible. Again, a lot of one-to-one group discussions between mentors and student teams were required to bridge the gap.

Validation with the stakeholders. We presented our analysis and design to the local co-instructors and got their feedback. Due to time constraints and difficulty in getting all stakeholders on board at the same time, we could not present our concepts to the community nor could we design it with them as per plan.

Width versus Depth. A paucity of time and the width of the exploration came in the way of going for depth of exploration. A longer duration course or the course divided into a number of connected courses might be a better approach for DfS.

Bordowa Specific Issues. Since most of our informants belonged to the Vaishnav community and some degree of religious alienation existed between them and Muslims of the area, the students got biased information. Some students became skeptical of visiting the Muslim community area due to this. But the scenario changed once a meeting was organized with the NGO working in computer literacy with Muslim women. Due to a paucity of time, this part of the village was explored only to a small extent. Another bias was introduced among the students when the priests, trustees, and museum curator kept on trying to connect everything with mythological or religious stories. The students found it difficult to look beyond mythology and religion and see the bigger picture of: *Why and how these stories and beliefs are built to create a particular sustainable way of living? How can we leverage this part of* "*Bordowa-ness*" *in today's context?* This brought in a lot of confusion and at times rejection of the connections as valid design cues. Through discussions we could, to some extent, resolve the conflict and create the sustainability connections.

78.5 Discussion

The key insight that we gather from our experience of conducting the course on S. DfS is one course which introduces students to the basics of sustainability, LCA, and system design is too heavy. The course can be rather divided into two courses: (1) introduction to sustainability and LCA; (2) system design for sustainability.

India being a country with diverse socioeconomic contexts, we also need to train our students accordingly. Hence, the first course, mentioned above, can have a project focus on industrialized contexts, while the second can have a focus on SEE. Through the two courses, we can also convey the idea gradually: *How can we shift from eco-performance (making things greener) to eco-practice (making things which promote green practice/consumption)?* DfS is a holistic design thinking process and its introduction early in the design program can be experimented with a *design in the sustainability context* approach. The need for one-to-one interaction of mentors with students is very high. Considering the number of students that a full class will have (~ 50), avenues for involving more number of mentors with diverse backgrounds need to be worked out.

The *Sustainability Design Orienting* (SDO) toolkit from MSDS [6] is a helpful tool which aids in analyzing the existing systems' sustainability characteristics, conceptualizing sustainability-oriented new ideas, and comparing the sustainability improvement/worsening. This tool or any other tool does not capture the same specifically for traditional and grassroots knowledge and values systems. Thus, there is a need for developing appropriate tools which can help to gather this information; aid in analyzing their impact on long-term SD at the personal, family, community and/or national level; design; and compare the sustainability improvement/worsening.

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Chapter 79
Mismatch of Education and Job: A Study on Design Professionals in India

Upasna Bhandari and Deepak John Mathew

Abstract With design and engineering education being conceived around the same time in post-independent India, design education lags behind in growth when compared to engineering education in India today. Research has shown that engineering education received support from government and industry in the initial years due to which it expanded exponentially. Design, however, still does not find a place in school education system and social system. This creates a gap in education for those who wish to pursue design as a profession. Therefore, using a sample size of 200 profiles of Indian design professionals from professional social networking Web sites, this study aims to investigate if there exists a mismatch of education to become a design professional in India. The nature of this study is not conclusive, but to open scope for discussion and further research in the direction of strengthening design education in India.

79.1 Introduction

Indian Institute of Technology was established at Kharagpur in the year 1950, followed by four such institutes at Delhi, Mumbai, Kanpur, and Madras to meet the growing needs of the post-independence India. In 1958, with the India Report submitted by Charles and Ray Eames for the setting up of a design institute in India, National Institute of Design in Ahmedabad (1961) and the Industrial Design Centre in the Indian Institute of Technology Bombay (1969) were founded by the Central Government of India [1].

Hence, both, design and engineering education, were viewed as significant steps toward developing a new and powerful country. Over the 70 years since independence, while the fields of engineering and design have grown individually, a

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wide gap is found when compared with one another. A significant body of research is available for growth of engineering education and profession in India [2, 3], but little empirical research has addressed the growth and status of design education and profession in India.

Therefore, the purpose of this paper is to observe the growth of design education in India and to find out the match or mismatch that exists within the education qualification of design professionals in India.

79.2 Engineering and Design Education Statistics

79.2.1 Rise in Institutes

By the year 1970, there were four institutes established for engineering education and two institutes were founded for design education. As per records, currently, there are 10,355 colleges in India offering engineering education [3] and nearly 982 colleges offering design [4].

79.2.2 Student Enrollments

All Indian Survey on Higher Education (2015–16) reveals enrollments for engineering and design disciplines, both at undergraduate level and postgraduate level. It is found that while 4,250,183 students enrolled for engineering education at undergraduate level, only 12,261 students opted for design education. For postgraduate studies, enrollments for engineering totaled to 261,065 and only 2012 students enrolled in the field of design [1].

This data indicates a gap in the growth of design education when compared with engineering education, since both the fields were conceived in the same time period. Hence, it becomes imperative to revisit the stages of change for both the fields.

79.3 Engineering and Design Institutes

Figures 79.1, 79.2 and 79.3 from above indicate the difference in growth of engineering education and design education in India. In order to understand this difference more elaborately, one needs to understand the growth chart of the institutes first established in both of these fields of education. For this purpose, the National Institute of Design and the Indian Institute of Technology are studied below as the change or growth in these institutes eventually has led to the change or growth in their corresponding field of education today.

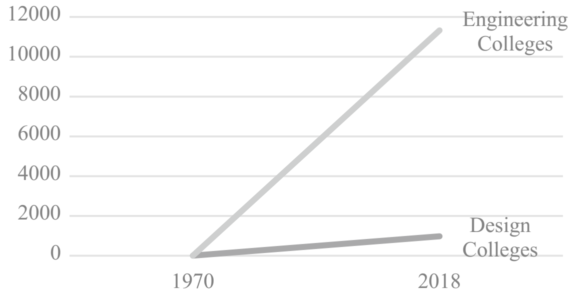

Fig. 79.1 Rise in the number of design and engineering colleges from 1970 to 2018

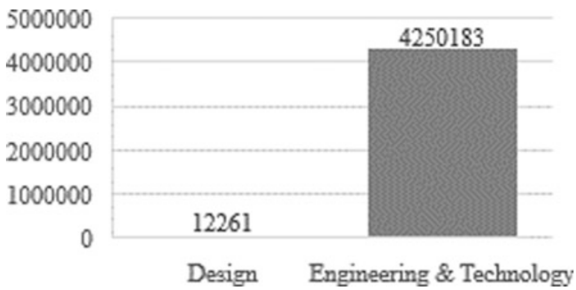

Fig. 79.2 Enrollment at undergraduate level in design and engineering [1]

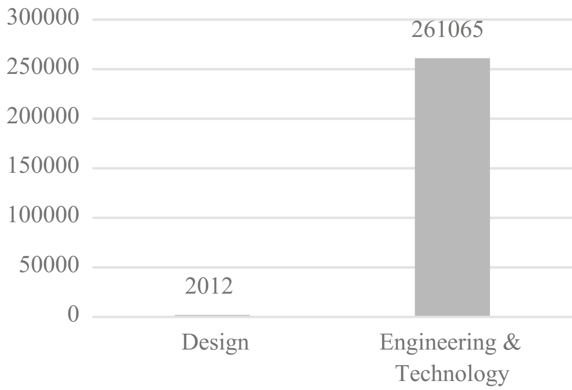

Fig. 79.3 Enrollment at postgraduate level in design and engineering [1]

79.3.1 About National Institute of Design (NID)

Ranjan M. P. in his lecture for Torrent Management at Ranikhet in March 2012 discussed the history of NID [5]. Some of the key points relevant to this study are:

- NID started the undergraduate programs in 1970 as the First School Leavers Professional Education Programme in Design in India.
- In an era of license Raj (1947–1990), most of the design disciplines at NID suffered from lack of support from industry and the government, while the

Indian Institute of Management (IIMs) and the Indian Institute of Technology (IITs) got considerable support in those days.
- NID education got international acclaim and recognition but was all ignored here in India, due to the poor record of publication.
- After the year 2000, the intake of students for the undergraduate program increased to 100 students a year, from 40 and inclusion of 150 students for postgraduate programs. Unfortunately, the growth in faculty strength did not take place at the same pace.
- The year 2007 saw the adoption of National Design Policy by the Central Government that led to the opening of four new NIDs in India. Till then, one NID with two centers at Gandhinagar and Bangalore was existing, making it to a total of five NIDs in India today.

79.3.2 About Indian Institute of Technology (IIT)

Similarly, in 2008, a report by Banerjee, Rangan and Muley, Vinayak P by the name engineering education in India [2] highlighted the following points that were relevant to this study:

- In 1950, the first IIT was established in Kharagpur.
- Within a decade of the first IIT, four more IITs were set up.
- The first technical institute of India was Thomson College of Engineering and was set up in 1847. This was subsequently ordained as IIT in 2001.
- There are a total of 23 IITs in India today.
- The Institute of Technology Act, 1961 declared the IITs to be 'Institutes of National Importance.' Under this act, a high degree of autonomy was given to IITs and a unique framework for the funding, admission, and academic development of IITs as privileged institutions was created [6].
- More than 40 courses are offered undergraduation and postgraduation level across all IITs collectively.

79.4 Initiatives for Design in India

The potential of design goes beyond the definition of aesthetics and functionality. There are a growing number of applications and utilities that can be answered best through design, and thus, many initiatives are being taken by the government, industry, and the design community to strengthen design in India.

79.4.1 National Design Policy

In the year 2007, The Government of India adopted National Design Policy. The policy will look at a wide range of issues from the demand as well as supply side. It will look into design education, design use, setting of design standard, etc. [7].

79.4.2 Design Innovation Centre (DIC)

The basic purpose of setting up of Design Innovation Centers is to promote a culture of innovation and creative problem solving, to promote knowledge sharing, and to enhance interdisciplinary design-focused education, research, and entrepreneurial activities [8].

79.4.3 Open Design School (ODS)

Open Design School (ODS) aims to ensure maximum reach of design education and practice in the country through free sharing of its courseware digitally [9].

79.4.4 National Design Innovation Network (NDIN)

National Design Innovation Network (NDIN) is envisioned to further the reach and access of design education by forming a network of design schools that work closely with other leading institutions of industry and academia, NGOs, and government [9].

79.4.5 Design Education Quality Mark

In order to create and maintain academic standards, program design, approval and program monitoring, and review for design education institutions in India, the India Design Council has developed a Design Education Quality Mark [10].

79.5 Challenges Faced by Design Education in India

The absence of design education in school system in India poses a two-way challenge. One, the students are never aware of 'design education' until they reach 18 years of age, and two, parents never hear the word 'design' in a formal educative context.

The awareness level about design is growing, but the emphasis is still on superficial attributes such as aesthetics, and the deeper aspects of structure and performance are not yet in the public perception, and these need to be achieved by education and awareness building [5].

79.5.1 School Education

According to a collaborative project of the Hasso Plattner Institute of Design (d. school), the School of Education (SUSE), and teachers in local schools, it was found that while the students at the best schools are getting experienced to design, public schools find them difficult to conceive [11]. Just like science, math, social sciences, and languages are taught in schools, there is a need for design to be introduced as a part of the curriculum at the school level. This way, the students who are interested in pursuing design as a specialized field of education can advance into their chosen fields right after 12th standard. As Don Norman quoted, 'I think that the current emphasis on STEM—science, technology, engineering, and math—needs a "D," for design' [12].

79.5.2 Family Influence

According to research, family influence is a significant factor affecting the career decision-making process. [11, 13]. In the absence of any awareness about 'design' and its prospects in the academic and industrial world, design as career is seldom a first choice. A study on Indian college students in USA confirmed that even though second-generation children preferred non-science majors more than their first-generation parents, the majority reported that their actual majors were in science and math [14].

79.5.3 Resultant Mismatch

The above factors point toward a trend that leads to the selection of popular subjects like science for specialized education, irrespective of individual interest areas. This gap further translates into a mismatch of their interest in career and education. Hence, when pursuing further specialized education like postgraduation, these students are found to be taking a detour toward the subject of their interest, in this case, design. Such a scenario builds a mismatch between influenced education and the career of choice.

79.6 Studies on Mismatch

Studies of mismatch of job and education have been successfully conducted by various researchers with respect to mismatch between overqualified/overskilled/overeducated workers and their less satisfying jobs, across USA and Australia [14–16].

Hence, there is little empirical research available that details on the mismatch of education route and the resultant profession practiced. This gives scope for such a study to be undertaken keeping the design as the area of education and profession.

79.7 Statement of Problem

As per the report of British Council, in India, only 35 percent students pursuing master's programs in design possess a bachelor's degree in the same design discipline [10].

In response to this problem, our study proposes to investigate the education route taken by design professionals in graduate and postgraduate levels. Depending on the education graph, profiles are termed as 'match' and 'mismatch' profiles and are further analyzed to identify a pattern, if any.

79.8 Methodology

In order to investigate the match or mismatch of educational qualifications of design professionals in India, random selection of 200 profiles from professional social networking Web sites was collected and analyzed.

79.8.1 Definition of Terms

'*Match*' *profile*: a profile where both the graduate and postgraduate education are in design/art/architecture.

'*Mismatch*' *profile*: a profile where graduation is in science/commerce/arts and postgraduation is in the field of design.

79.8.2 Procedure

In order to conduct this study, a random sample of 200 profiles of Indian design professionals from professional social networking Web sites was obtained. These profiles were categorized as 'match' and 'mismatch' profiles on the basis of the graduation and postgraduation stream. The 'mismatch' profiles were further analyzed as per the stream of graduation and age group. The correlation between the variables of graduation stream and nature of profile was assessed through chi-square analysis with the help of appropriate tools.

79.8.3 Delimitations of the Study

This study serves to contribute toward the mismatch studies in the Indian context with specific attention to the status of design education in India. However, this study is not without its limitations.

First, only design professionals of Indian origin were considered for data collection. Second, design professionals with postgraduation as their minimum education qualification are considered for this study. This was a necessary constant to enable analysis of equally qualified profiles. Third, streams like art and architecture at the graduate level are not considered as a deviation for postgraduation in design.

79.9 Results

From the data collected across 200 profiles, Table 79.1 shows the proportion of 'match' and 'mismatch' profiles. As it can be seen, this proportion is almost merging to an equal share.

Tables 79.2 and 79.3 show further classification of 'mismatch profiles'. While Table 79.2 and Fig. 79.4 represent the division of graduation stream of the 'mismatch' profiles, Table 79.3 and Fig. 79.5 show the distribution of age group among the 'mismatch' profiles.

Table 79.1 Proportion of nature of profiles from the sample collected

		Frequency	Percent
Valid	Match	94	47.0
	Mismatch	106	53.0
	Total	200	100.0

Table 79.2 Division of graduation stream of 'mismatch' profiles

		Frequency	Percent
Valid	Science	84	79.2
	Commerce	15	14.2
	Others	7	6.6
	Total	106	100.0

Table 79.3 Distribution of age group of 'mismatch' profiles

		Frequency	Percent
Valid	Less than 25	4	3.8
	26–30	29	27.4
	31–35	36	34.0
	36–40	21	19.8
	41–45	8	7.5
	46 and above	8	7.5
	Total	106	100.0

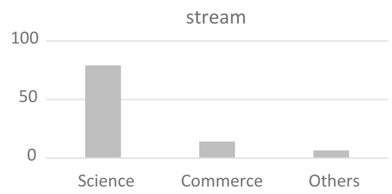

Fig. 79.4 Division of graduation stream of 'mismatch' profiles

Using chi-square technique to test whether the two variables—'nature of profile' and 'graduation stream'—are related to each other or independent, a null hypothesis was stated:

H0: 'Nature of profiles' is not related to 'graduation stream.'

As in the point (a) in Table 79.4, the expected count is less than 5, i.e., more than 20% (25%); we look at likelihood ratio instead of Pearson chi-square. Since *p* value (significant value) is .000 which is less than 0.05, we reject the null hypothesis.

Hence, we can conclude that nature of profiles is dependent on graduation background.

79.10 Summary, Discussion, and Conclusion

Based on the sample size under the study, the gap between the 'match' and 'mismatch' profiles is found to be almost diminishing. However, on further investigation using demographics, it was found that nearly one-third of the 'mismatch' profiles belonged to the age group of 31–35. This indicates a more likely

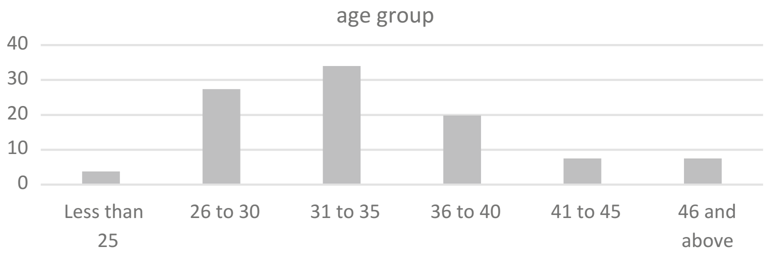

Fig. 79.5 Distribution of age group of 'mismatch' profiles

Table 79.4 Chi-square test

	Value	df	Asymp. sig. (two-sided)	Monte Carlo sig. (two-sided)		
				Sig.	95% confidence interval	
					Lower bound	Upper bound
Pearson chi-square	188.329[a]	3	.000	.000[b]	.000	.000
Likelihood ratio	249.776	3	.000	.000[b]	.000	.000
Fisher's exact test	237.517			.000[b]	.000	.000
No. of valid cases	200			.000[b]		

[a]Two cells (25.0%) have expected count less than 5. The minimum expected count is 2.82
[b]Based on 10,000 sampled tables with starting seed 2,000,000

trend of 'mismatch' among the digital natives. The low level of 'mismatch' among the younger age groups can be suggestive of a rising awareness of design among the digital millennials.

A majority of the 'mismatch' profiles were from the science stream who took a detour toward design at the postgraduate level. This percentage was drastically low in case of commerce stream and further low in case of others that included arts and social sciences. This data leads the discussion in multiple directions. One such implication suggests that the discontent with the field of study is found maximum in science as design professionals from science graduation background do not continue with science in their postgraduation. Another implication is that science might be the most favored choice at the time of graduation, but the design is the more preferred choice of profession by the science students. This lead to the formation of a null hypothesis (H0): 'Nature of profiles' is not related to 'graduation stream' which was then rejected and concluded that the 'nature of profiles' is related to 'graduation stream.'

From the results and findings discussed above, it is clearly established that there does exist a mismatch between design education and design profession. However, the aim of this study does not lie in analysis, but to investigate the reasons behind such a mismatch. The purpose of this study is to bring attention to design educators, scholars, and other stakeholders of design education. The delimitations of the study also give scope for further discussions like whether graduation in architecture is a form of mismatch for design professionals or not; whether this study holds valid for design professionals of other countries; and so on. Thus, this research looks forward to other connecting researches that question different variables to strengthen design education in India.

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Chapter 80
Colour, Music and Cross-sensory Perception

Shekhar Bhattacharjee

Abstract This is about a course in visual design named elements of colour, which has been taken by a group of faculty members of NID including me. The course is for B.Des. Foundation, and quite a few of years, it has been developed in a certain manner. It was discussed that for visual sensory perception, along with visual senses, another sensory perception is important, like touch is important for 3D visualization. For the perception of colour, the role of other sensory perceptions was discussed. It was found that sound and colour have connection in visual art in Indian and western art tradition for long. Artist of western tradition took inspiration from music and painted, and Indian Ragamala paintings were painted based on Indian classical music. To see how music and colour work, a workshop was conducted among student attending colour course. Four to six ragas were taken for three workshops conducted at different points of time. Approximately, 200 students participated in the first two workshops, and 15 students participated in the last workshop. There were a group of faculty members with me, who were also conducting the course. Each raga was played vocally as performance, and students were asked to paint their feelings immediately along with the raga, rendering through colour. The expressions were expected to be non-pictorial and non-representational (should be abstract). One by one, six ragas were performed by vocalist and students expressed their feelings on paper. After the performance, student's work was displayed while the name of the ragas was not revealed. So students did not know the name of the raga. Student's work had been put up under titles like Raga-1, Raga-2 up to six and had been exhibited. It is found that the colour palette of the student's expression has similarity with the colour palette of the miniature painting created on the same raga in Indian miniature tradition, and also, colour palette matches with the mood, expression, time and season of the raga described in Indian classical music text. This is a small pilot study, based on which more workshops will be conducted in order to investigate the phenomenon elaborately.

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80.1 Introduction

This is about a course in visual design named elements of colour, which has been taken by a group of faculty members. The course is for B.Des. Foundation, and quite a few of years, it has been developed in a certain manner.

Before the course, every time several meetings and discussions were arranged to develop the course towards the context. In visual design instead of only visual, focus is shifted towards complete experience, which is multisensory.

So in learning of visual design especially colour which is visual perception-based, what would be the role of multisensory or cross-sensory approach.

In existing research, it was found that for 3D visualization, with visual senses touch senses are very much involved. There must be role of other sensory experiences to visualization other than only visual senses. Research also shows that creativity is much more prominent to them who have cross-connection among the senses in brain.

Through discussion, the concept of synesthesia came out and later on elaborate study was done to connect learning of colour with it.

In synesthesia, one sensory experience can trigger other sensory experiences without having external stimuli of the particular sensory experience which is triggered. It has two approaches to address the fact, reductionist and holistic.

In neuroscience (reductionist) now, one can precisely measure brain activities through the scanner. In the case of synesthesia, it was found the two sensory areas in brain are nearby and connected. This connection occurs because of improper brain development. It is not supposed to be connected but it is. For example, if number sensitive area and colour sensitive area are connected then number and colour synesthesia happen. The people who have this will see number in colour. In the higher stage of synesthesia when the connection is more, it leads a person to be more creative. Creativity is a matter of connection.

Holistic point of view is saying that it is intermingling of senses as a whole. The experience comes as feelings. This is not the sum of the senses; it has a separate identity as experience. This is the highest degree of aesthetical experience also, mostly found in Haikus, Japanese poetic forms, which tried to evoke multisensory experience by mixing the senses absurdly in poetry. An illustration of this can be seen in the poetry of Basho.

"*Kane kiete*
hana no ka wa tsku
yube kana"

"*As the bell tone fades*
Blossom scents take up the ringing
Evening shade"

Here, in Blossom scents take up the ringing. It is not seen in real world which means scent does not has sound but the line tried to evoke the connection, and audience understands without doubt, and the feelings is conveyed.

We have already discussed that perception and visualization are possible by using multiple senses. It develops from the input of multiple senses. Now in study of colour, being aware of other senses along with visual, will make perception of colour deeper and vivid.

In this context, western music and art and Indian Ragmala paintings and Indian classical music are also investigated and introduced.

During the discussion, while we were thinking of other senses related to colour, we realized sound and colour have relation, especially Indian classical music and miniature painting. So it was decided that Indian classical music and the impact on student's colour interpretation would be the central theme of the course.

80.2 The Workshop

These are groups of three workshops, conducted over three years. Each workshop was divided into few steps or parts. I am describing two workshops here—1 and 3.

For auditory stimuli, Indian classical music was taken. Music for auditory stimuli was selected for a specific reason. It has been seen that from the very early period, music and painting have close relationship and have influenced each other, and colour is a major element of painting.

From the sixteenth century to nineteenth century in Indian miniature painting, in all the schools, paintings on Indian classical music had been done. In Indian classical music, form of the music is called raga. Raga is a Sanskrit word; raga means colour or tint of colour. There are six main ragas, and each raga has number of wives, sons and daughters. There are different systems to categorize ragas, but according to all categories, there are six main ragas: Bhairava, Malkos, Hindol, Dipak, Megha and Sri. Artists from different miniature schools painted different ragas.

A short of the experiment was designed where Indian classical ragas were given as auditory stimuli and participants were all design students, from different cultural backgrounds from different parts of India. There were almost equal numbers of male and female participants. In first phase, each raga was played vocally or instrumentally as performance and students were asked to paint their feelings immediately along with the raga rendering, through colour. The expressions were expected to be non-pictorial and non-representational (should be abstract). One by one, six ragas were performed by vocalist or from sound system students expressed their feelings on paper. After the performance, student's work was displayed. Name of the ragas was not revealed. So students did not know the name of the raga. Student's work was put up under titles like Raga-1, Raga-2 up to six and was exhibited.

80.2.1 Workshop-1

Six ragas were taken for the workshop—named

(1) **Ahir Bhairav**, (2) **Shree**, (3) **Bageshree**, (4) **Sarang,** (5) **Miya Malhar** and (6) **Basant**.

Approximately, 100 students participated.

80.2.2 Workshop-3

Main structure of Workshop-3 was more or less similar like Workshop-2. This time ragas were

(1) ***Shri*** (evening—15 mts), (2) ***Sarang*** (summer—13.21 mts), (3) ***Mia ki Malhar*** (monsoon—8:58 mts) and (4) ***Basant*** (spring—14:55 mts).

Fifteen students participated.

80.3 Fact Finding from the Workshop

Now, the ragas which had been taken for the workshops 1 and 3 will be discussed, and the expression of the Indian miniature artist on these ragas also will be discussed. Along with this, expression of the students as art work will be discussed too.

80.3.1 Workshop-1

Raga-1

In this workshop, raga one was not attempted by most of the participant, there was no data as such, and that is why this was not taken into account.

Raga-2

The second raga of the workshop was Shree. According to Indian classical music theory, this raga is an evening raga. It is performed between 4 and 8 pm. The mood is of majesty, feelings of love also emerge, and according to Pandit Omkarnath Thakur, it is the time when nature and human are at peace. The disembodied spirit becomes active (lord of whom is Shiva).This is the time to practice black magic also. So the atmosphere created by the raga is a little spooky and fearful.

Two examples of student's expression are presented which are painted without knowing about the raga (Fig. 80.1).

Fig. 80.1 Student's expressions 1 and 2 (from left to right)

In first example, colour palette is a combination of cool and warm colour, such as red, orange, yellow, yellow orange, blue and black. These colours together create an atmosphere of sunrise or sunset. Also seeing few of the composition exploration, some mysterious form and arrangement can be found, which creates very mysterious atmosphere.

In second example, colour scheme shows the environment of late evening with combination of cool and warm colour, such as red, orange, yellow, yellow orange, purple and blue along with greys and black. The day is almost at an end. But more precisely, it also shows a very mysterious and spooky environment.

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

https://upload.wikimedia.org/wikipedia/commons/6/65/Shri_Raga%2C_Folio_from_a_Ragamala_%28Garland_of_Melodies%29_LACMA_M.70.59.jpg. 19/9/2018, 11.00 am.

https://www.metmuseum.org/art/collection/search/37871. 19/9/2018, 11.10 am.

http://indosfera.ru/?c=2049-zhivopisnye-izobrazheniya-severo-indiyskih-rag.

Raga-3

In this workshop, raga three was not attempted by most of the participant, there was no data as such, and that is why this was not taken into account.

Raga-4

The fourth raga of the first workshop was Sarang. Classical theory says this is a raga of early afternoon raga and the season is summer. Basically, the rasa of this raga is Sringara (erotic). It creates a romantic and mystic atmosphere. The Sarang was named on famous fourteenth-century music theorist, Sarangadeva. The Sarang raga consists of a group of seven, each of which is combined with some other ragas. Today when Sarang is given as the raga, it usually means Brindavani Saranga, a member of the Kafi thaat. In the Ragmala, Sarang is listed as a putra (son) of Sri Raaga.

Observation of these three expressions on the students by hearing the raga shows that majority of the expression has very warm colour palette. Although cool colour had been used, even that enhanced the warmer feelings of the composition. So red, yellow, orange, pink and tint and shade of it were mainly used which brought the feelings of warmer part of the day. In third composition, green has been used, which brings the essence of summer. In a way, the use of red and green and blue shows the feelings of romantic and erotic atmosphere. According to Bharata's Natyashastra, green is the colour of Sringara Rasa. The colour is used in the third and fifth compositions (Fig 80.2).

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

http://gallery.kangraarts.org/shop/ragamala-series/raga-sarang/. 20/9/2018, 10.59 am.

https://www.flickr.com/photos/asianartsandiego/4838263130/in/dateposted/.

https://interest.nz/pin/465137467744800145/www.p. 20/9/2018, 11.17 am.

https://www.harvardartmuseums.org/visit/exhibitions/3497/pavilions-of-love-a-ritual-space-in-indian-painting. 20/9/2018, 11.53 am.

https://www.pinterest.nz/pin/433119689142008449/. 20/9/2018, 12.44 am.

Fig. 80.2 Student's expressions 1, 2, 3 (from top left to right)

Raga-5

Raga-5 was Miya Malhar or Megh Malhar. It is sung in rainy season. Rasas are majorly Karuna and Sringara (Fig. 80.3).

Colour palette of the students in painting 2 was mainly blue and green. These are cool colours which represent rainy season. The other two paintings, i.e. 1 and 3, have red, yellow orange with green and blue, which represents Sringara rasa.

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

https://www.exoticindiaart.com/product/paintings/raga-megha-HC47/?&signout=1. 18/8/2018, 4.42 pm.

https://www.pinterest.nz/pin/433119689156775065/. 20/9/2018, 4.00 pm.

https://www.pinterest.co.uk/pin/263953228141392496/. 23/9/2018, 5.50 pm.

https://www.exoticindiaart.com/product/paintings/baramasa-month-of-shravana-HK38/.

https://in.pinterest.com/pin/608478599625544043/.

Raga-6

Raga-6 was Vasant. This raga is played in spring season, any time of a day. Performed in slow tempo, this gentle melody depicts quiet joy. It has *karunaras.*

Presently, the only example shows colour palette of red, orange, green, pink, blue, etc. These are all energetic colour. The combination of it shows freshness, festiveness, joy. The form selected for the colour is wavy and linear, which seems like a slow rhythmic progression, like slowly spreading over the canvas. This could be an example of quiet joy (Fig. 80.4).

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

https://www.artgallery.nsw.gov.au/collection/works/82.1997/. 23/9/2018, 12.22 pm.

https://upload.wikimedia.org/wikipedia/commons/a/a8/Vasant_Ragini_Mughal.jpg. 23/9/2018, 12.22 pm.

http://www.harekrsna.com/sun/features/09-10/features1859.htm. 23/9/2018, 12.33 pm.

http://www.britishmuseum.org/research/collection_online/collection_object_details/collection_image_gallery.aspx?assetId=123729001&objectId=183933&partId=1. 23/9/2018, 12.46 pm.

Fig. 80.3 Student's expression

Fig. 80.4 Student's expression

80.3.2 Workshop-3

In third workshop, four selected ragas were taken. After two workshops, it had been noticed that on few ragas participants responded more. So in third workshop, those ragas had been selected. Ragas were

(1) ***Shri*** (evening—15 mts), (2) ***Sarang*** (summer—13.21 mts), (3) **Mia ki Malhar** (monsoon—8:58 mts) and (4) ***Basant*** (spring—14:55 mts).

Among these ragas, Basant was vocal while rest of the ragas were instrumental. Fifteen participants participated (male and female) and were from across India with vivid cultural background. Age group was within 20s.

The workshop proceeded in a similar manner as earlier workshops. Ragas were played one by one, and participants expressed through colour on A5 paper given to them, after each raga was played. Name of these ragas was not revealed, and this time set of colour pastels were given to them. Some notes also were written by the participants on each raga. Paper size was A5. The expressions were expected to be non-pictorial and non-representational (should be abstract). One by one, four ragas were played and students expressed their feelings on paper.

Raga-1

First raga of the workshop was Shree. This raga is evening raga. In first workshop, we have already discussed the raga. Refer to Raga-2 of Workshop-1.

Fifteen expressions of the raga were investigated. All the expressions were non-pictorial and non-representational. These were very intuitive and spontaneous expressions.

Among 15 expressions, majority of them had colour palette of orange, red, blue, purple and yellow. Other dominant colours were green, black and brown. We see the first set of colour palette mostly either in sunrise or sunset. This raga is of evening, and the colour palette is seen to be matching (Fig. 80.5).

Fig. 80.5 Student's expression

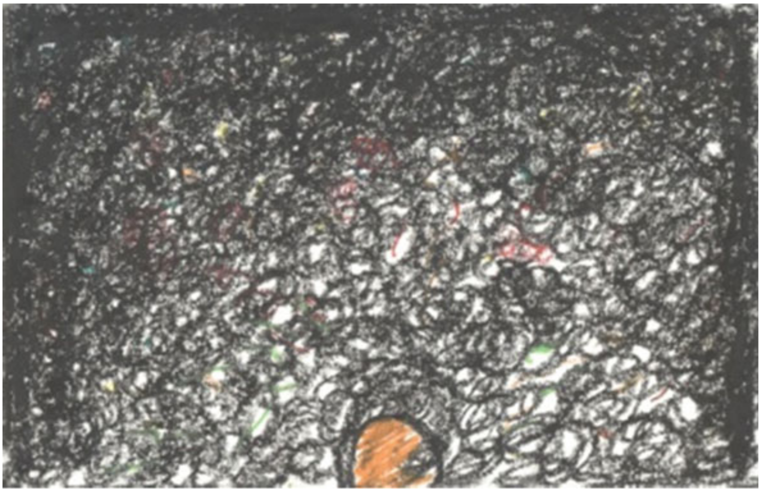

Fig. 80.6 Student's expression

It is said the raga is a little spooky and fearful; also, palette and composition as shown in the above expression (Fig. 80.6) shows that.

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

https://upload.wikimedia.org/wikipedia/commons/6/65/Shri_Raga%2C_Folio_from_a_Ragamala_%28Garland_of_Melodies%29_LACMA_M.70.59.jpg. 19/9/2018, 11.00 am.

https://www.metmuseum.org/art/collection/search/37871. 19/9/2018, 11.10 am.

http://indosfera.ru/?c=2049-zhivopisnye-izobrazheniya-severo-indiyskih-rag.

Raga-2

Sarang was the second raga of the third workshop. Fifteen expressions were investigated; out of 15, 7 expressions had the palette of the mood created by the raga. Sarang is an early afternoon raga of Indian summer. Rasa of this raga is Sringara (erotic). It creates a romantic mood.

Colour palette of these 7 expressions is red, crimson, yellow, orange, brown, then purple, blue and green also. Apart from colour, the way these colours were put in terms of lines and colours is also interesting. The way in which colour lines are put on picture plane actually depicts the dryness and harsh light of summer (Fig. 80.7).

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

http://gallery.kangraarts.org/shop/ragamala-series/raga-sarang/. 20/9/2018, 10.59 am.

https://www.flickr.com/photos/asianartsandiego/4838263130/in/dateposted/.

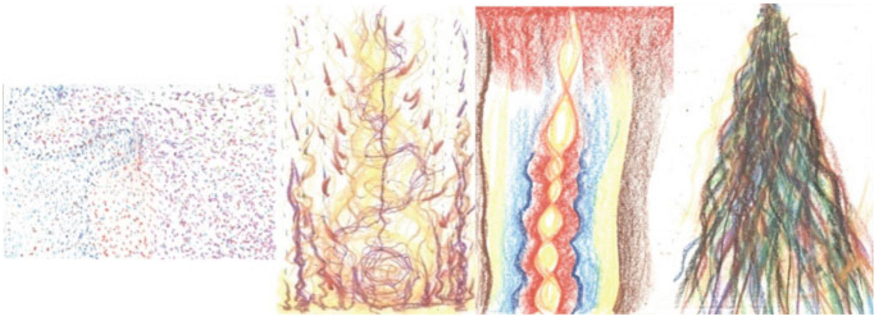

Fig. 80.7 Student's expression

https://interest.nz/pin/465137467744800145/www.p. 20/9/2018, 11.17 am.

https://www.harvardartmuseums.org/visit/exhibitions/3497/pavilions-of-love-a-ritual-space-in-indian-painting. 20/9/2018, 11.53 am.

https://www.pinterest.nz/pin/433119689142008449/. 20/9/2018, 12.44 am.

Raga-3

Raga-3 was Mia ki Malhar or Megh Malhar. This is the raga of rainy season. Rasas are majorly Karuna and Sringara.

Among 15 expressions, 11 expressions have colour palette which matches the mood of the raga. Palette can be divided into two groups. One group has cool and dark colours, while another one has bright colours like purple, yellow, light green, red orange (Fig. 80.8).

Warm colour group expresses the festivity of the season as it comes after summer (hot) season, while cool colour expresses the coolness of monsoon.

Same miniature paintings had been taken to investigate the colour palette, repeating about these paintings.

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

Fig. 80.8 Student's expression

https://www.exoticindiaart.com/product/paintings/raga-megha-HC47/?&signout=1. 18/8/2018, 4.42 pm.

https://www.pinterest.nz/pin/433119689156775065/. 20/9/2018, 4.00 pm.

https://www.pinterest.co.uk/pin/263953228141392496/. 23/9/2018, 5.50 pm.

https://www.exoticindiaart.com/product/paintings/baramasa-month-of-shravana-HK38/.

https://in.pinterest.com/pin/608478599625544043/.

Raga-4

Fourth raga was Basant. The month of Basant (spring) in India is much pleasant. This is right after winter, and summer is yet to come. One of the most colourful festivals that takes place this time is Holi, the festival of colour.

This raga is played in spring season, any time of a day. Performed in slow tempo, this gentle melody depicts quiet joy. It has *karunaras.*

This is the only composition rendered vocally. Lyrics of the particular song say that all other ragas are the companion of bridegroom and the raga itself is the bridegroom. So the song creates the mood of a marriage ceremony. That is all about the mood of the raga, raga of celebration.

All the 15 expressions have vivid colour palette, with red, yellow, orange, green, blue and purple. Also, the way colour had been applied is very vibrant, dynamic and rhythmic which expresses the mood of festivity (Fig. 80.9).

In Indian miniature painting, colour palette of few Indian miniature paintings has exactly similar colours which we see in student's artwork. Links of the miniature paintings are given below. One can open to check.

https://www.artgallery.nsw.gov.au/collection/works/82.1997/. 23/9/2018, 12.22 pm.

https://upload.wikimedia.org/wikipedia/commons/a/a8/Vasant_Ragini_Mughal.jpg. 23/9/2018 12.22 pm.

Fig. 80.9 Student's expression

http://www.harekrsna.com/sun/features/09-10/features1859.htm. 23/9/2018, 12.33 pm.

http://www.britishmuseum.org/research/collection_online/collection_object_details/collection_image_gallery.aspx?assetId=123729001&objectId=183933&partId=1. 23/9/2018, 12.46 pm.

80.4 Conclusion

It is difficult to conclude with anything concrete with this small experiment and sample size, but a pattern is emerging that creative people have the ability to convert auditory experience into visual representation in terms of colour.

So what happened is, audio stimuli had been given in form of Indian classical music. Now, this music has separate time and season to play and depicts particular emotion. This is claimed that during listening to the music similar kind of mood of the time and season would be experienced. After listening to the music, participant expressed through colour and the colour palette generates similar kind of mood which had been experienced by the participant during listening to the music. This has been understood by investigating the palette. Also, these palettes were compared with the colour palette of Indian miniature paintings based on the music which had been taken for auditory stimuli and similarity were found.

The process followed for the expression was intuitive, experiential and synthetic.

So finally to say, creative people have capacity to visualize same mood/time of a day/season/emotion of auditory stimuli and can express through colour. Intuitive, experiential and synthetic processes have important role to play in this creative process.

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11. https://www.youtube.com/watch?v=BWGNWgBk76
12. https://www.youtube.com/watch?v=6LorvbKs79w
13. http://nautil.us/issue/26/color/what-color-is-this-song
14. https://in.pinterest.com/pin/373306256591306144/?lp=true. 23-1-2018, 5.19 pm
15. https://www.youtube.com/watch?v=6LorvbKs79w. 14/6/2018, 11:37 AM
16. http://www.sikhiwiki.org/index.php/Sarang. 18/9/2018, 11.13 am

Chapter 81
Essentials of Gamification in Education: A Game-Based Learning

Anjana Ramesh and Ganesh Sadashiv

Abstract Design innovations are vital to the future of educational development, and such advancements are always unprecedented. Gamification is one such new tool of modern education, which can be used to solve concerns related to the quality of chemistry education. Our research on Indian education techniques led to the study of how Indian classroom setting works with the student–teacher relationship and how this psychologically impacts on a student's overall learning capacity. The purpose of this paper is to (1) understand student's subjective proficiency through gamification in chemistry (2) and design an innovative framework for enhancing skill-based learning. A board game design called "The Lab City" can be deployed to teach the fundamental concepts of chemistry to students more efficiently. The main aim is to create a better experience of learning for students of the chosen age group by understanding their mental models. The game design is tested and analyzed through two frameworks: (a) Mechanics–Dynamics–Aesthetics framework, i.e., MDA framework and (b) Design–Play–Experience, i.e., DPE framework in real time. Results included in the assessment of the tests taken to point out the critical differences between traditional method and board game-driven learning, which indicate better learning and more in-depth understanding in favor of the board game aided in teaching–learning environment. Significant learning benefits specific to the subject knowledge include recognition of elements and their atomic symbol. We argue that a carefully designed game-based learning environment can leave a more profound impression of academic content by making teaching more fun and engaging. We describe the design of our game-based learning environment and present the results of preliminary investigations that demonstrate its potential.

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Smart Innovation, Systems and Technologies 135,
https://doi.org/10.1007/978-981-13-5977-4_81

81.1 Introduction

Education is an age-old, formal, or sometimes informal process of acquiring new information, skills, habits, and beliefs. Traditionally, lectures consist of teachers verbally communicating information to the students, and students are passively receiving [1] and encoding it in their memories. The contemporary method of teaching that takes place inside the classroom setup ends the age-old tradition of [1] gurukul system. In India, knowledge of science and math is considered to be very worthy and necessary. Every school system has science and maths as compulsory subjects till tenth standard. Chemistry is one such subject which has equal parts of the theory and practical aspects. However, instruction of chemistry is yet to become futuristic and on a par with the modern-day needs of the students as they still learn the concepts from textbooks and presentations. Many recent studies suggest that the passive method [2] may not be the most effective way for students to learn. By creating a passive learning environment, the educators have no way of knowing what misconceptions lie in the student's mind in order to be able to correct them. In order to make them comfortable with the new concepts, they have to be engaged in an active teaching environment [3], where students are responsible for their learning. One example of an active learning classroom is a gamified system of education. Lab City, a board game based on periodic table and reactions in chemistry, has been designed and developed for gamifying chemistry learning and improving the interests of the students toward the subject. Games are always considered to be fun and enjoyable by students. When educational concepts are combined with what they perceive as exciting, their level of comprehension will increase as it is voluntary. This research elaborates the study and findings of this game used in an actual teaching environment and an analysis of the game through frameworks.

81.2 Literature Review

Board games are tools of entertainment governed by a set of rules played according to specific themes and concepts. When used in the right context, they can be deployed as tools of education as well. Learning with board games [4]—a paper by Elizabeth N. Treher talks about the myths that still drive education systems today. Being a chemistry teacher, she has had several first-hand experiences with student learning, where once, despite giving the students an open book test, most of them failed because they were not able to synthesize, analyze, and apply what they read. In the research paper "learning by experience," a popularly accepted concept is a myth because by the age of 30 most of the Americans would have had a million experiences with a dollar, yet only a few might be able to draw a dollar exactly. Experience alone is not enough to learn new concepts; it needs to be combined with relatable and meaningful experiences to have some effect. The paper also argues that hands-on and heads-on the combination is the key to quality learning and board games can provide this. Another study by Ruhl et al. [5] found that individuals exposed to lectures where the instructor paused for two minutes every 12–18 min did significantly better on a comprehensive test 12 days later and with free recall at the end of the lecture. In fact, an improvement over the control group was two letter grades jump. In a board game, pauses are natural, i.e., when players discuss possible answers and strategies. Ruhl and colleagues point out that short lectures are consistent with research indicating the ability to retain information that drops significantly after 10–20 min. In the paper “What makes chemistry difficult” [6], it is mentioned that many students fail at grasping fundamental chemistry concepts and these remain unchanged throughout their school life and when difficult concepts are added on top of this, they are unable to manage. The study also categorized the problems of learning such as lack of planned course content, too many technical terms, lack of interest by students. Since there are many difficulties that students face in understanding small concepts which shape their whole perception of chemistry and due to enough research work is done in understanding problems faced by students, an attempt to pilot a study toward chemistry has been made. Many games have been developed toward learning science and math, but not in the area of chemistry which is another driving force behind this research.

81.3 Gap Analysis

Chemistry is a demanding and challenging subject which may not be easy for all students to grasp with a passive learning environment. It is duly noted that teachers are trying to make their classes engaging and entertaining, but fruitful results have not come out of them. This research possibly helps more designers to focus their attention on the need that has arisen a better learning tool for students of all capacity. The research was done on the topics of chemistry, gamification, student learning, and educational setup which have paved the way for the analysis of a board game aided in chemistry education. Studies to prove the credibility of board games to teach serious subjects have to be carried out to help the students to learn better.

81.3.1 Idea Generation

As seen in Fig. 81.1, after a brainstorming session on factors concerning the Indian education system, it was noted that high school students have difficulty in primarily learning the science subjects due to sudden introduction of complex concepts into the curriculum. These concepts are combined with a passive learning environment that introduces an unwanted fear in students about grasping the subject knowledge. A small survey conducted among students led to chemistry being their most feared

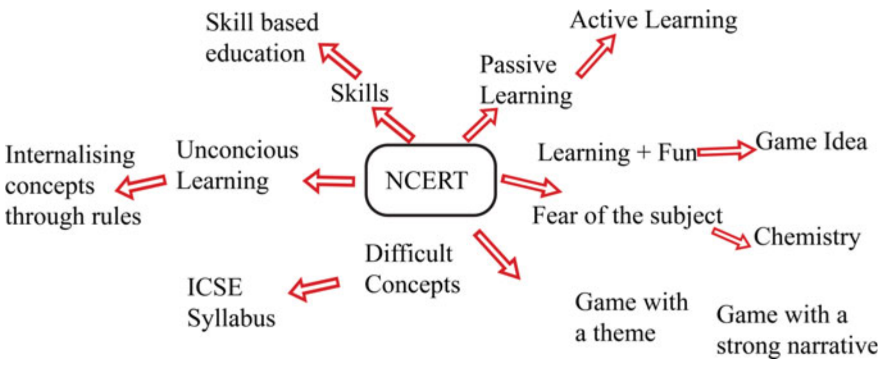


Fig. 81.1 Brainstorming

subject. Therefore, choosing "chemistry" as the topic of instruction, the idea was to create a learning tool suitable for students of all learning capacity, their behavior, and interests.

81.3.2 Solving Problems with Board Games

Lee [7], author of The Multiplayer Classroom, designed coursework for his students using aspects of gamification and was one of the first professors to use game-related terms in teaching. Lee's work resulted in the whole class going up by one grade alphabet. MIT Comparative Media Studies department has already prototyped a couple of games which teaches physics, psychology, and environmental studies. So, the world is moving toward an integrated learning system—combining education and games which have proven to be successful. Further the idea to create a developmental tool for high school students, this theory of integration proves to be helpful in developing the mechanics of the game.

81.3.3 Case Study

Before developing Lab City, a case study was conducted on a board game—Survival: Doom [8] to understand the game structure and frameworks involved in the game. It helped to understand the idea behind gameplay, player's psychology, and learning curve involved in the game. It gave an insight into the mechanics, dynamics, aesthetics needed to develop an innovative product. Survival's gameplay of managing resources to reach a destination and planning actions to be ahead in the game gave an idea of how an innovate game-based product could be designed.

Analyzing the game regarding MDA [9] and DPE [10] framework also helped in constructing the same.

81.4 Analysis Through Mechanics–Dynamics–Aesthetics (MDA) Framework

MDA framework [9] is a formal approach to understand game design. It is a tool to help developers to understand the game through different perspectives and also examine existing games to figure out their credibility. The MDA framework supports the view that the designer develops the mechanics, and the main focus is on forming the rules of the game, whereas the player's main role is experiencing the game. The rules are instantiated at playtime and influenced by the player's input, forming the dynamics (run-time behavior of the game). The aesthetics of the game is the resulting emotional responses of the player while playing. The game developed has been examined through this framework to prove its credibility. In Table 81.1, a detailed analysis of mechanics involved in Lab City has been explained.

Dynamics: Dynamics describes the run-time behavior of the mechanics acting on player inputs and each other's outputs over time. The outcome of the mechanics designed by the game developer is the dynamics. Players will strategize their moves and decide when to use what power, have a competitive feel that will be manifested through the storyline and character ideologies, they will have a zeal to win the game while simultaneously trying to comprehend concepts, Excitement, fear and usage of strategy while playing unconsciously.

Aesthetics: *Aesthetics* describes the desirable emotional responses evoked in the player when they interact with the game system. Any player or end user will first experience emotions related to the game design which could be based on the colors used, words written, concepts involved, possibilities the game has to offer, and

Table 81.1 Mechanics—MDA framework

Mechanics	Mechanics describes the particular components of the game, at the level of data representation and algorithms
Game turn	Player rolls the dice, moves the tokens, trades with other players
Action points	Players are given fixed number of resources to spend
Cards	There are five sets of cards used in the game, event cards, teleportation cards, special cards, reaction cards, element cards
Catch up (progress toward victory)	The game gets progressively tricky as players move ahead, to move from one zone to another multiple tries are required
Dice	Dice movement is used for moving ahead and resolving conflicts
Management	Players need to cautiously tread as they have limited resources to finish the game

Table 81.2 Aesthetics—MDA framework

Aesthetics	Aesthetics in game
Sensation	Visual: board, cards, tokens, periodic table; touch: dice, tokens, cards; feel: nervousness, pressure, excitement, innate need to win
Fantasy	The game takes place in the fantasy world of “Lab City” and derives its theme from Greek mythology
Narrative	The story is about each Greek god trying to be the first to save Lab City—to please their father Kronos
Challenge	Player’s actions have consequences later on whom they befriend and whom they target could cost them.
Fellowship	Trading facilitates fellowship
Expression	Students with different types of personality have a common ground to express themselves

other such factors. In Table 81.2, the list of emotions and how the game satisfies them have been discussed.

81.5 Analysis Through Design–Play–Experience (DPE Framework)

The Design, Play, and Experience (DPE) [10] framework was created as an expansion of the MDA framework to address the needs of serious game design for learning. The DPE framework presents a language to discuss design, a methodology to analyze design, and a process to design a serious game for learning. Discussing Table 81.4 in detail, the *first layer talks* about learning, where the designer focuses on designing the content and pedagogy to facilitate learning as an experience by the players. While playing, the players will be taught the concepts designed in learning. In Lab City, the game facilitates the learning of concepts mentioned in Table 81.1. The game allows for this learning through visuals, the gameplay, and mainly by the completion of event cards in the game. The results were successfully discussed in the next section. The *second layer talks* about storytelling through the game. Storytelling can take up two perspectives’ [10]—one being the designer’s perspective, which is the outcome of the story crafted by the designer to deliver the game to the players. This includes the narrative, characters, theme, and plots as decided by the designer. The player’s perspective includes the designer’s story combined with the interactions the players develop during gameplay. Lab City has an equal weighage given to both designers and the player perspective of storytelling. *The third layer* briefly explains the rules, resulting dynamics and emotions connected with the game (much like the MDA framework) [9]. Chemistry has been carefully molded with the story of Greek mythology, where characters are chosen to suit the chemical aspect they represent. The *last layer*—user experience deals with the visual interactions of the game that needs to be equal parts entertaining and elicit the desired learning outcome. The interface of game design is crucial as players come into contact with the game, first, with these interfaces. It includes everything the user can hear, see, feel, and interact with which forms the game experience combined with mechanics and rules. It is true that all the layers are interdependent and changes in one will affect one or all the layers. A good learning goal combined with mechanics that have a high co-relation to this goal will result in a game that can facilitate better learning. Lab City's mechanics are on a par with what it aims to teach the student.

81.6 Game Idea

The idea for Lab City began with a need to provide a universal tool for Indian high school students to learn chemistry. The target audience for the game was fixed as seventh- and eighth-grade students, 12–13 years of age, as this is the age when basic core concepts of chemistry are introduced to kids. The game would have room for children of varying learning abilities and a framework to enhance their skill set. The ideas went through a series of iterations and drafts. Iterating helped in realizing that a narrative-driven game was better suited for the chosen target audience (Table 81.3).

81.6.1 Scope of the Game

The game would help students to learn the fundamental knowledge required to understand the subject of chemistry. The core gameplay is to reach the central laboratory first, by finishing the reaction given to the player at the beginning of the game. The concepts that students will familiarize and eventually learn areas mentioned in Table 81.4

- These concepts mentioned in Table 81.5 are fundamental to understand chemistry and once mastered will remove the fear from the students.
- The whole project aims to help students to overcome the fear of subjects and change their perspective toward learning.
- It will be the duty of the instructor and the game to alter their false mental misconceptions about learning.

81.6.2 Experiment

In order to test the functionality of the game and its teaching capacity, the experiment was conducted with the help of the game model as shown in Fig. 81.2 with

Table 81.3 DPE framework

	Design		Play		Experience	
Learning	Content and pedagogy	Periodic table, elements, atomic structure reactions	Teaching	Basics of chemistry, terms, properties, and visual memory	Learning	Good memory, familiarity and association, relatable concepts
Storytelling	Setting and narrative	Greek mythology-driven story	Storytelling	Through gameplay and card handling	Story	Drives each player to prove themselves
Gameplay	Mechanics	Rules formed through events	Dynamics	As players follow the rules, they begin to start strategizing	Affect	Excitement to trade, win, and loss of coins
User experience	User interface	Festive and colorful, cards, coins	Interaction	With the pieces, players, rules and themselves	Engagement	In the form of group learning, involvement

Table 81.4 Concepts learned

(a)	Atoms and elements
(b)	Periodic table
(c)	Neutralization reaction
(d)	Atomic structure of elements
(e)	Water being a fire extinguisher
(f)	Anions and cations
(g)	Atomic number of 20 elements
(h)	Properties of elements

Table 81.5 Learning outcomes targeted through design

Concepts	Objectives of the concepts
(1) Periodic table	Meaning and importance, usefulness in understanding chemistry, simplicity and design of the table, retention of properties of the table
(2) Elements	Atomic number, atomic structure, developing the skill to relate elements with the periodic table, properties of certain elements
(3) Neutralization reaction	Brief meaning, the formula of the reaction, reactants, and products needed and produced, respectively
(4) Anions and cations	Identification of ions, their representation

five students of St. Mark's Convent, Rajajinagar, in three stages. Stage 1 consisted of teaching the randomly chosen group of seventh graders—concepts related to the periodic table and some terms related to neutralization—in a completely healthy environment mimicking that of an ordinary class. Stage 2 consisted of teaching them the same concepts but with the help of teaching aids such as pictures, associations, and colorful graphics. The final stage, Stage 3 involved making the students understand the gameplay of "Lab City" and making them play the actual game. After the completion of each stage, the children took a written test to prove what they had learned from the specific teaching process. These experiments were of vital importance as it proved the efficiency of Lab City to bring about a change in the teaching process and also allowed us an insight into the minds of these young kids.

81.6.3 Components

Pool A testing (teaching consistent with a regular classroom): The chosen group of five students was seated in a classroom. The following concepts were taught to them using a blackboard and chalk piece, with no actual visuals and only drawings on the board (Fig. 81.3).

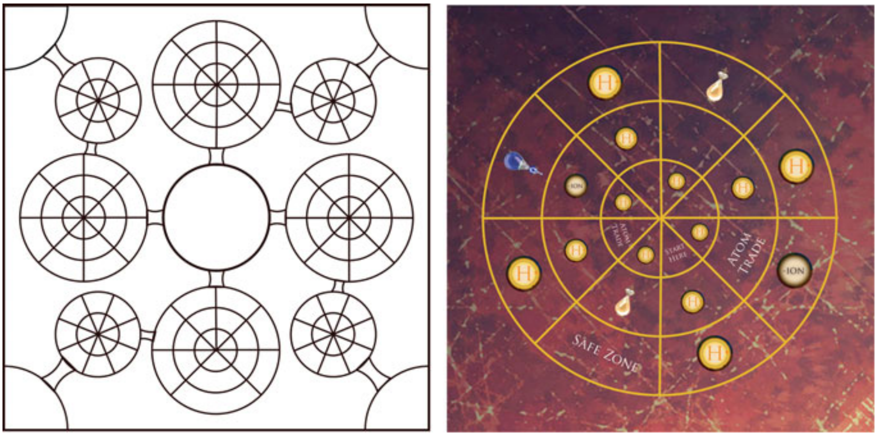


Fig. 81.2 AutoCAD outline and final graphic

- A small introduction to chemistry, difference between atoms and molecules
- What is a neutralization reaction? Difference between cations and anions
- The periodic table and its properties—noble gases are at the far end; the table moves from left to right with an increase in atomic number and decrease in electron affinity
- A few drawings on the board—atomic structure of elements, how a reaction is written down.

The session took about 30 min to cover all these topics rationally and in relation to each other. The children were excited to learn as I was their new teacher, but not all of them paid attention throughout and not all of them understood all the concepts at the pace at which I was teaching. After the session, they were asked to take a written test. The sample size of the experiment was 5 students, who were selected by the method of random sampling. The mean age of the students who participated in the test was 12 years. All these students are from St. Mark's Convent, Rajajinagar, which is affiliated to the Karnataka Secondary Education Board. The students are comfortable in English speaking and understanding.

In Pool A testing: Mean of questions which were rightly answered:

$$\begin{aligned} \sum \text{Mean} &= \text{Sum of Observations} \div \text{Number of observations} \\ &= (4+3+3+5+4) \div 5 = 4 \end{aligned} \tag{81.1}$$

Fig. 81.3 Mean of Pool A

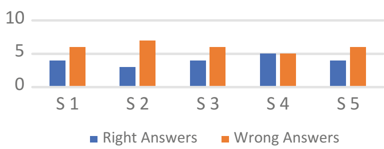


Fig. 81.4 Mean of Pool B

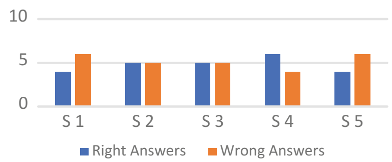
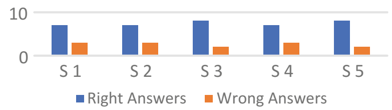


Fig. 81.5 Mean of Pool C



Mean of questions which were rightly answered: = (6 + 7+6 + 5 + 6) ÷ 5 = 6

Pool B testing (*with colorful visuals used in the game to help understand topics*): Pool B testing involved teaching the same concepts mentioned in "Pool A" but with a visual association for every concept as designed for the board game and analogies that the students could relate to. Also, Pool B was conducted after a time period of 1 day after Pool A. The same questionnaire was given to them to take the test, and results were noted. The mean of the right answers calculated as per (81.1) was 4.8 and wrong answers were 5.2 (Fig. 81.4).

Pool C (*playing the game*): The last level involved instructing the students the rules of "Lab City" and letting them explore the game. The students were visibly excited and thrilled to be playing a game after two days of learning. They actively participated in asking doubts, conversing with each other freely with no tension and compelled need to remember concepts. The game allows players to honestly take on the role of their characters (Greek gods), and the students seemed to enjoy it. After completing the game, their feedback was collected, and they were again asked to answer the questionnaire. The overall result showed an increase in correct answers given by students (mean = 7.4) and a comparatively lesser wrong answer (=2.6) (Fig. 81.5).

81.7 Learning Outcome

Before discussing the results of the tests conducted, the idea to generate a learning tool by understanding how each student differs in learning concepts led to set some objectives of learning that the game would attempt to achieve. The research was focused on a skill-based learning development, and hence, certain concepts were fixed as vital aspects of the game to be designed. Table 81.6 outlines these learning concepts and what the game would invoke in the students who played it. The overall objective of the design would be to encourage a positive attitude of students toward chemistry and urge them to learn it out of a process of enjoyment rather than compulsion. The learning objectives so targeted (refer Table 81.6) seek to diminish the myths around chemistry—being a difficult topic to understand by seamlessly incorporating them into the design of the game mechanics and gameplay.

81.8 Results

The learning curve across all three tests is shown in Fig. 81.6 and shows the growth of learning across all three tests for the same sample group. In test one, which was "teaching on a par with current system," the learning is hardy 40% for 5 students. In test 2 done with Pool B method of teaching—"teaching using colorful visuals and associations," the learning curve has increased to 50%.

In test 3, where teaching was done with the tool developed—"Lab City—a board game for chemistry," the results have hiked up to 72%. There is a steady and clear growth seen in the learning intake from the selected group of students, which showcases the need for applying such a technique to a classroom setup for a better learning process to occur.

81.8.1 Discussion

As seen in Fig. 81.6, there is a gradual increase in the learning curve from Pool A to Pool C. The method of teaching is directly proportional to results, i.e., as teaching methods improve, the result of understanding on the student's part also improves. Pool A testing was done with a minimal teaching technique, through the use of a strict teacher–student setup with a board and chalk. This gave results that were only 40% effective. We also need to keep in mind that not all students have an equal learning capacity. Pool B was taught using exciting visuals and themes to associate the concepts with. This sample provided results that were 52% effective. This could be because although the students were able to understand certain concepts with visuals certain higher-level concepts required meaningful experience-based learning, the introduction of a teaching aid in the form of a game which breaks the monotony of a normal classroom environment, to imbibe the knowledge. Pool C was the most successful out of the three trials, providing 72% useful results among students. The game created a casual environment which allowed the students to relax and concentrate. They were not burdened with the subconscious thought, that

Fig. 81.6 Learning curve

whatever they hear, they needed to remember. Moreover, they were having fun and understanding concepts of chemistry simultaneously which makes learning a fun experience.

81.9 Conclusion

This study with concrete results proves that when administered in the right manner, a board game can facilitate in-depth learning in students, especially the tricky subjects. Students in the current generation have access to a lot of information through the Internet and other means of technology. If the knowledge acquired in the educational setup is not interesting enough for them, they will simply cast it aside. It is time to take the next leap in our educational setup and bring in the so-called unconventional means of teaching methods to help the students. Based on the findings from the study, the paper proposes a "mixed learning environment" where teachers and students alike will stand on the same platform with no hierarchical differences and learn by using interactive and education-based board games. The classroom will have a casual atmosphere where knowledge sharing is possible freely. Such a framework combined with traditional rules could help better the lives of every student, placing them all on the same level.

81.9.1 Future Scope

This study can inspire several leading game designers to design games for learning. Complex subjects like calculus, organic chemistry, quantum physics, psychology could be made simpler and less intense by the use of carefully designed board games. Small steps could be taken in educational setups to welcome such theories so that education becomes more about the quality of learning rather than quantity.

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Chapter 82
Bringing Industry to Classrooms: Experiences in Conducting a Product Design Laboratory

Palaniappan Ramu and G. Saravana Kumar

Abstract In teaching a product design laboratory course in an engineering design department, it is desirable for students to be able to build products to appreciate design theory, the need for requirement elicitation, concept ranking, functional and conceptual decomposition and other related concepts. This allows them to understand the design life cycle and also provides a sense of accomplishment when they develop a product hands-on. It also becomes eminent to appreciate adaptive design and design with constraints for an existing product. We experimented by inviting industry collaborators to share their design problems and let students brainstorm and come up with solutions for the same. This paper will discuss our experiences on such an experiment over multiple years.

82.1 Introduction

As an inventor, Leonardo was an astonishing genius. Although he lived over 450 years ago, he foresaw the coming of advanced technology and filled his notebooks with thousands of drawings for new machines and weapons, many of which anticipate twentieth-century engineering techniques. We see him designing armoured tanks, steam guns, ballistic missiles, flying machines, air screw, parachutes, helicopters, underwater diving suits, water turbines, movable cranes, lifting jacks, gearboxes, to name a few [1, 2]. Each of his inventions is a source of wonder and excitement, displaying both Leonardo's awesome intelligence and an incredible anticipation of the future. When it comes to inventors, the contributions of Thomas Edison demonstrate the value of systematic approach to invention, design and product development. Edison was meticulous and painstakingly thorough when it came to design. He tested hundreds of different materials in his search for perfect filament to use in his incandescent light bulb (including bamboo and sewing thread) [3]. His style had its advantages: He is still on record as one of the most prolific

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(and famous) inventors in US history with 1100 patents! This clearly emphasizes the fact that to succeed in a new product development, the design process must be planned carefully and executed systematically. In particular, an engineering design method must integrate many different aspects of designing in such a way that the whole process becomes logical and comprehensible. To that end, the design process must be divided, first into phases and then into distinct steps, each with its own working methods. The curriculum at engineering design department has a course on functional and conceptual design and aims to present systematic engineering design process with the latest information about general theory and practice. As a continuation of the learning objectives of this course, the students undertake two instances of product design laboratory—one in the second year and the other in the third year. The first offering was originally envisaged to be a product dissection laboratory. Later, projects were introduced that give hands-on experience in product design practices. The paper discusses the evolution of the product design exercises that we gave as part of the laboratory and the outcomes.

82.2 Structure of the Product Design Laboratory

The product design laboratory's main learning objective is to "learn product design through dissection". To cater to this objective, the laboratory was structured to include mainly dissection experiments of common consumer product and understanding mapping of function, concept and form. Specifically, the students did product teardown and generated concepts for redesign. As per the credits, the students met for the laboratory weekly once for 3 h exercise. A typical semester has about 14 weeks, and a typical batch size of engineering design is 60 students. The students were divided into 12 groups, and a sample laboratory semester schedule as described in Table 82.1 was developed.

82.2.1 Team Building

The first session was aimed at introducing the laboratory objectives and organizing the students into teams and team building through hands-on problem-solving. Session here refers to a laboratory class, which is typically 3 h of class. The problem statement and resources for building the product were given to the student teams, and the students were to successfully complete the product with limited resources and meeting time constraints. Problem statements were kept simple considering the time and resources given to the team. An example problem statement "Build a 3-dimensional free standing load bearing structure using only the materials provided" is described in Table 82.2. The problems were chosen to give sufficient scope to organize them as teams, identify skills and assign roles and responsibilities, apply creative thought and some basic engineering knowledge.

Table 82.1 A typical product design laboratory schedule

Session	Activities	Details
1	Introduction	• Laboratory objectives • Laboratory schedule • Pre-laboratory preparation • Academic requirements • Report writing • Evaluation • Team-building exercise
2–10	Product dissection experiments	
11	Design project/product identification	• Product scoping • Market needs • Customer survey • Product planning
12	Functional analysis	• Need statement • Product metrics • QFD • Functional decomposition
13	Product/portfolio architecture	• Concept generation • Concept selection • Sketches
14	Examination	

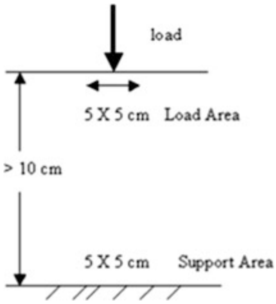
82.2.2 Product Dissection

The product dissection sessions constituted of product teardown and analysis exercises with an aim to understand:

- functions, forms and their relationship,
- product architecture,
- study different types of mechanical subsystems and components like drives, transmissions, joints, mechanisms, control elements and
- develop new product designs.

The products chosen were mostly mechanical/electromechanical household appliances and few engineering products from automotive and biomedical domains. The students learned the process of disassembling and assembling the products, gathered information about the subsystems and understood function through flow of energy, signal and material and the product form in terms of layout and architecture. A sample dissection of a product is provided in Fig. 82.1. The students accomplished the dissection in a particular laboratory session and came to the next session with the report on the product essentially containing the answers to the following questions:

Table 82.2 A typical team-building exercise

• Objective: Build the structure with maximum stiffness and as tall as you can • Rules: – 30 min to design and build your tower – Use only the materials provided Tape Newspaper – The load-bearing structure to be evaluated for its stiffness – The team with the tallest and stiff structure that follows the rules wins 	 Team outcomes  Evaluation

- What does the product do?
- How does it do it?
- What makes it do it?

Through the multiple sessions, the students went through this process on different products cycled over the groups. A teaching assistant was assigned to a product, and he/she guided the students through the process. To bring variety to the study objectives and remove boredom, each product dissection had some specific objectives like:

- Product use with customer focus,
- Understand manufacturability,
- Product sustainability and environmental concerns,
- Ergonomics and aesthetics, to name a few.

The session-specific objectives and product cycle ensured that every student group had unique product study for each session.

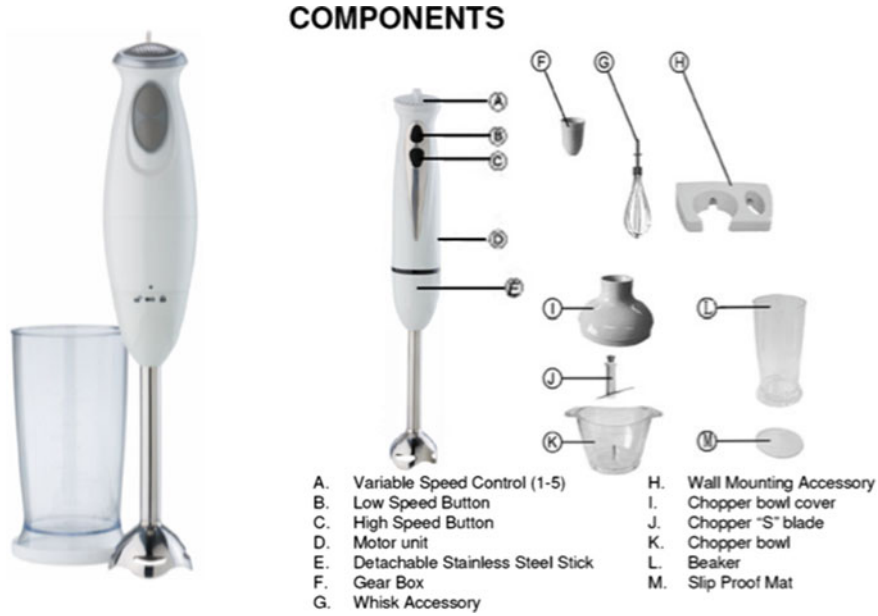


Fig. 82.1 A sample product dissection

82.2.3 Design Project

The students did a product design project towards the end of the semester over three sessions in the initial course offering(s). The products chosen were similar to the products dissected by the students, but the session objectives were focused towards redesign for new product development. The student teams worked on customer survey, employed QFD and applied the learnings on function to form mapping to generate concepts. The sessions were heavy on brainstorming and were moderated by the teaching assistants. The teams chose a single concept out of the generated concept by applying concept selection principles and prepared sketches. However, over the years, we learned the need to include product building as well instead of just stopping with the design. Hence, we started giving problem statements where the students were expected to build products to address the problems. The objectives and structure of the design project went through a series of evolutionary improvement based on the student's feedback and our own experience.

82.3 Design Project Evolution

Over the first two sessions of offering this course, we realized that the students need better means of connecting the learning between theory and laboratory and the design projects executed by students over three laboratory sessions were far from achieving this objective. Hence, we experimented with semester-long team-based design project component to the course so that they can "learn through doing" by applying the design concepts learned to an interesting design problem. In that session, the student teams were to design an "Aquaped" and there was a design competition based on that. The project was inspired by the common water strider, a small (approximately 12 mm) insect that is capable of "walking" on, or running across the surface of the ponds, by employing the surface tension for support (Fig. 82.2a). The students were required to design and construct the device that will allow a person to "walk" on the surface of a body of water and demonstrate the device. The design project had several constraints like any real-world design problem, like:

- Aquaped is to be propelled by the person, with no external power supply.
- The action of the person should be similar to normal land walking gait.
- The "walk-in" and "walkout" should be unaided.

Each team is to design, construct a working prototype and demonstrate the same. The prototypes developed by the students were tested in the shallow sections of the institute swimming pool (Fig. 82.2b). Performance metrics like average speed over a 8-m walking track, simplicity of design, innovation and cost were used to evaluate the design and prototype. The students enjoyed the experience, and based on the feedback, this kind of projects became a permanent component from that session.

Later, to give real-world concept design experience, industrial design problem statements were introduced for the design project in 2012 session. Hence, we proposed a template to an industry partner where a generic problem statement is to

a) Common water strider b) One of the team project

Fig. 82.2 Aquaped project

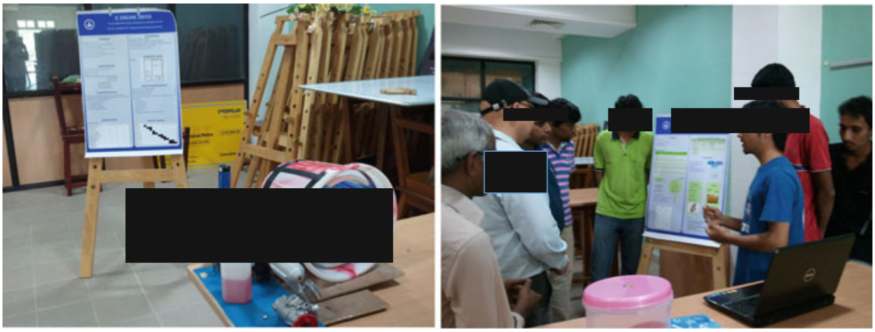


Fig. 82.3 Projects from industry and its evaluation

be proposed by the industry and the different student groups will come up with different solutions to the same problem. The students followed a design theory framework learned in the previous courses. The instructors aided by teaching assistants, on a weekly basis, monitored the progress. The monitoring was questioning the design process adopted and feasibility of ideas. Care was taken to preserve creativity, and adherence to framework was not insisted so that out-of-the-box thinking was possible. Once in every month, the industry representative interacted with the students to understand the progress. This was an extremely important aspect because the legacy of the industry chose solutions that were practically applicable over scientifically sound solutions. The students were evaluated by the final design accomplishment and the proof-of-concept prototype developed by the industry partner (Fig. 82.3). Industries such as Whirlpool®, Titan® and Saint-Gobain® to name a few over the years supported this activity. The industries apart from giving problem statements were also financially supporting the design iterations. Thus, we brought industry problem for out-of-the-box thinking and conceptual design as part of learning and also in the process delivered few evaluated and novel design concepts to the industry. Several patents (close to 12) were filed for promising designs that came through this activity over years (details of which are held for the purpose of review).

82.4 Case Study

In this section, we present a particular year's industry partner's engagement as a case study. The partner was interested in developing a shared bicycle concept with the following objectives:

(i) To explore different strategies for central locking system in a bicycle,
(ii) To explore different strategies for variable speeds in a bicycle,
(iii) Propose and develop a prototype for a shaft drive.

Our responsibility was to:

(a) Brainstorming possible solutions, concept selection matrix,
(b) Any relevant CAD models that are developed,
(c) Literature review,
(d) Functional and conceptual diagrams of the proposed solutions (for objectives (i) and (ii)),
(e) All design and analysis (for objective (iii)).

The industry partner's responsibility was to share statistics on the bicycle dimensions and constraints in the shared bicycle market.

Initially, the problem statements were only presented peripherally to the students. Once they decide on the topics, the complete statement was provided and immediately a brainstorming session was conducted without the help of the Internet or any support. Each team or participant wrote the keywords of a basic solution that they could think of. Once all teams were done, we were able to cluster and mine that information to show how most of them thought of similar solutions. Subsequently, they were briefed on patent search and how to look for information to identify gaps to contribute. Every week, the team worked on a report, which was shepherded by the teaching assistant. During the product design laboratory hour, each team discusses the progress with the instructors to understand the feasibility. In such a fashion, once in every three weeks or so, the industry partner also participates in the discussion to explain the perspectives from the industry side. Based on these pruning and discussion, the students converge to a solution. The students are also expected to develop a proof-of-concept prototype. One of the solutions developed is presented below. The details are available in the patent document, which is withheld for review purpose.

82.4.1 Summary of the Invention

The present invention relates to a variable speed gear mechanism eliminating chain shift for achieving variable speed with minimum number of components and a unique modularity in design comprising,

(i) Input disc, with a set of gear teeth cut out on its face in the form of concentric rings,
(ii) Movable shaft, with gear teeth cut out on the surface,
(iii) Bevel gear, inclined on the surface of gear teeth.

Wherein, mechanism developed involving input disc of chain drive bicycle driven by the chain that goes over the sprocket with unique dimensions of shaft gear and spline gear which helps in reducing the bending deflections. The developed mechanism achieves variable speed with minimum number of components and has a unique modularity in design. Thus, the mechanism developed is a lighter, more compact, minimizing bending deflection and can be projected as an appended mechanism for existing chain-driven cycles without any change in the original design of the bicycle.

82.4.2 Description of the Drawings

The above drawings depict the construction of the invention. Figure 82.4 illustrates the basic construction demonstrating the working of the concept of the invention. Figure 82.5 illustrates the embodiment of the invention, which can be attached to a bicycle to facilitate variable speed. The following are the list of various parts used in the construction of the invention:

(1) Face gear (A disc with concentric gear teeth cut out on its surface),
(2) Pinion gear which meshes with the face gear,
(3) Female spline shaft which meshes with the gear shaft attached to the pinion gear,
(4) Fixed housing which houses the female spline shaft and the gear shaft,
(5) Driving bevel gear attached to the female spline shaft,
(6) Driven bevel gear attached to the sprocket of the bicycle via an output shaft,
(7) UCP clamps to secure the input shaft and the output shaft to the mount,
(8) Channel which acts as a mount which can be attached to the body of the bicycle,
(9) Spacer block,
(10) Input shaft which is driven by the user,
(11) Output shaft which drives the sprocket,
(12) Movable gear shaft attached to the pinion gear, which meshes with the female spline shaft.

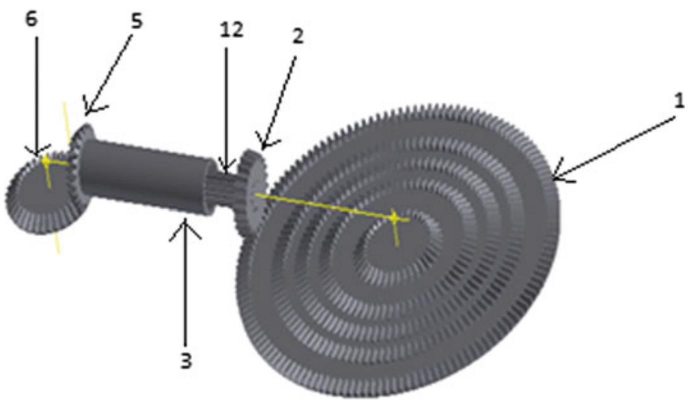


Fig. 82.4 Components demonstrating the core principle of the invention

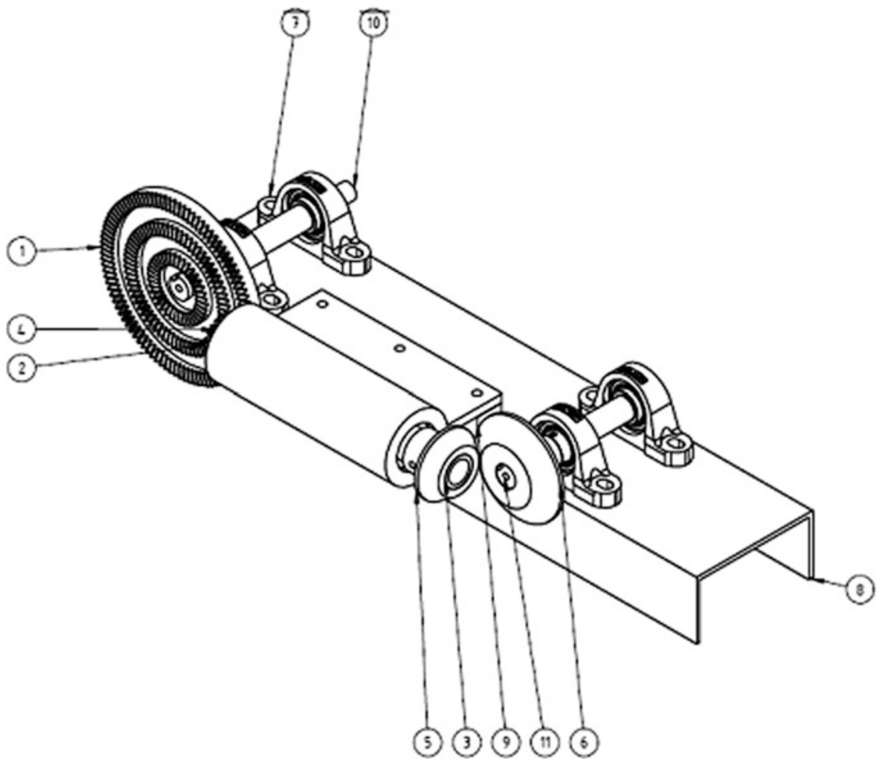


Fig. 82.5 Practical embodiment of the concept, an appendage that can be attached to a bicycle

The concept involves an input disc which has a set of concentric gear teeth cut out on its surface which is called as face gear (1). This face gear is mounted on an input shaft (10) which in turn is secured to a channel (8) by means of UCP clamps (7). The input shaft is driven by the user, either directly or via a chain connecting the front sprocket of the bicycle. A pinion gear (2) attached to one end of a movable gear shaft (12) meshes with the concentric face gears. The gear shaft meshes with a female spline shaft (3) in such a way that it enables the axial motion of the gear shaft, resulting in the axial motion of the pinion gear which in turn results in the pinion gear meshing with different sets of concentric face gear, thus enabling variable speed due to the different gear ratios of the face gear. This bevel gear drives the driven bevel gear (6) which is attached to an output shaft (11). The output shaft will be connected to the rear sprocket of the bicycle and will be secured to the channel (8) by means of UCP clamps (7). Thus, the output shaft drives the rear sprocket which in turn drives the bicycle. The channel can be mounted on the body of the bicycle and provides support to the entire setup.

82.5 Summary

This paper documented our experience experimenting in the product design laboratory. Real-time problems faced in the industry were given as problem statements for students to brainstorm and come up with solutions. The underlying idea was to preserve creativity and out-of-the-box thinking while treading the classical path of formal design starting from need elicitation to concept ranking to proof-of-concept prototyping. Our experience shows that we came up with a framework where all the stakeholders benefitted. From a course-deliverable perspective, we were able to file patents, which gave the students a sense of accomplishment and belief that they can utilize their core engineering knowledge to design valuable things.

Acknowledgements Thanks are due to students, teaching assistants, technical staff and participating industry partners.

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Chapter 83
Do We Have the Right Candidate? Reflections on the Selection Processes for Admission to the Design Program in India

Ravi Mokashi Punekar and Avinash Shende

Abstract The paper examines the selection process followed among the leading schools of Design in India and highlights the challenges to the selection of candidates for the increasing high number of applicants seeking admissions to Design programs at the undergraduate and postgraduate levels. It considers the complexity in making the selection process more inclusive the different strata of society. It reflects if the candidates selected were appropriate based on how they performed subsequently during their educational period on campus. The paper raises concerns if it is time to experiment with new formats to the selection process keeping in times with a technologically empowered society. It questions if spread of mobile technology and emergent trends like additive technologies may have far-reaching bearing on the traditional model of Design learning and if selecting candidates for the millennium generation of Design learners will face different criteria for selection.

83.1 Introduction

Indian democracy, it is said, is colorful, complex and noisy. Perhaps shades of this are also reflected in the domain of education in India. It is very evident in the competitiveness seen in admissions to professional Higher Educational Institutions (HEIs') of learning. Each year, nearly 1.5 million seats are offered in engineering [1] from among nearly 8700 institutes recognized by the All India Council of Technical Education (AICTE). These institutes are government funded and others that are private institutions. More often, the processes of admissions are centralized

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through common entrance examinations organized by each state. Among these HEIs', those recognized as 'institutions of national importance' funded by the government, are relatively few. Education fees are relatively subsidized, attracting a large number of applicants seeking admission to these institutions. The centrally funded institutions of national importance such as the IITs offer around 12,000 seats distributed among the 23 different IITs' spread across the country. Students are admitted by qualifying the all India Joint Entrance Examination (JEE), which is considered to be one of the toughest entrance examinations in the world for admissions. Considering that nearly 4.5 lac applicants apply for admissions each year, one can imagine the competitiveness for admissions. Democratic fair play is reflected in the complex dimensions of inclusiveness in the selection process that involves general category applicants and in addition reservation of seats for including the economic and social status for different sections of society and the differently abled.

Let us for a while pause and think—not of those who actually made it, but for the many more that did not. Were there alternative programs options for them to seek admissions to such institutions of excellence? Design education leading to a career in the growing creative industry in India can perhaps be posited in this alternate path for such aspirants. They have the option to pursue programs in Design at the undergraduate or postgraduate levels. The establishment, developments and shifts in the admissions to such creative professional programs have to be seen in the larger background of a historical perspective if one is to better understand the emerging scenario of Design and Design education in India today. This will enable to better predict its future directions in these changing times if one is to meet aspirations of the millennium generation who will lead the creative industry in India in the future.

83.2 On Design Education in India

Career opportunities for professionals in the rapidly growing creative industry in India find its reflection in the spurt of Design educational institutions (it has risen to nearly 80) in India today. These institutions offer a variety of different types of focus. For instance, in the domain of fine arts and applied arts, the J.J. School of Art, Mumbai; Department/s of Fine Arts at M.S University, Baroda; University of Chandigarh and University of Delhi among others are well known internationally. They offer professional degree programs at both the undergraduate and postgraduate levels. The institutions of national excellence such as the National Institute of Design; IITs in their departments of Design; Indian Institutes of Science; National Institute of Fashion Technology located at 6 cities across India; and other reputed schools run by private institutions such as Srishti Institute of Art, Design and Technology; School of Design, MIT, Pune among many others offer a variety of programs in Design. These institutions have different fields of specializations to offer. These broadly include industrial Design; graphics, new media and communication Design; textile, fashion and apparel Design; gems and jewelry Design; accessories Design; exhibition Design. The advent of digital technologies has opened new avenues for specialization in interaction Design; Design management; artificial intelligence; and usability and experience Design. At the turn of the millennium, the aspirations and expectations of the Gen-X seek opportunities involving information, communication and entertainment (ICE). The increasing gap between the demand and supply of these trained professionals has only increased. We have around 7000 qualified Design professionals today. Another 5000 are in Design schools undergoing training through formal Design education [2].

This is no mean indicator of the recognition and the demand for Design as an alternative choice for a professional career. The Design profession clearly invokes the creative spirits of innovation to meet human aspirations. It is seen as a profession than integrates the core stream of engineering; cognitive psychology focused on human needs; and aesthetic sensibilities in the development of products, services and systems through good form meeting end users tacit experiences. ‘Good Design is Good Business’ forms the mantra for a successful career and enterprise.

83.3 Ethos of a Design Education Program in India

Unlike scientific research that seeks a new generation of knowledge through controlled experimentation, statistical analysis of co-relational variables and theoretical speculation, the Design profession derives its insights through uncontrolled and ill-defined problems drawn from a humanistic perspective rooted and inspired in the everyday.

The two schools of Design Viz. Hochschule für Gestaltung (HfG) at Bauhaus and later at Ulm, West Germany in the early twentieth century have perhaps had the strongest influence in the studio-based model of learning followed among most Design schools in India [3]. Creativity and problem-solving abilities that meet human needs are the central ethos of learning that drive Design institutes.

Design thinking has seen different phases in its development. Modes of Design research and enquiry on aspects of creativity and innovation in the Design and development processes following rigorous experimentation have evolved from the early twentieth century. Guilford [4] argues that a person with a Hi-IQ may have a creative aptitude. Amabile [5] and Mumford [6] in their experiments concluded that more often innovation is preceded by creativity. Considering the different aspects of human intelligence, De Bono [7] suggests tools and methods to help one to be trained in creativity. Referring to the nature of creativity, Shende [8] suggests the soft and generative nature of creativity and the hard and developing nature of innovation.

Directions of the Design discourse have witnessed different dictums such as ‘Form follows function’ and ‘Form follows emotions’; while others such as ‘Design Semantics’ and ‘Post modernism’ have drawn from theoretical frames that emerged in the humanities and social sciences. Commenting on Design research, Schon [9] suggests that perhaps there is a need for identifying a 'new institutional epistemology' for Design in the present times. Most of these arguments and discussions on Design knowledge form part of the education discourse and are contained in its curriculum and delivered by Design educators through creative means and interactions with students. Design and studio assignments aim to assess and evaluate outcomes toward the professional abilities of the designer. But in the admission of students to a Design program, how does one select the right candidate? What constitutes the selection process? What are the assessment methods of selecting the candidate having an aptitude for Design learning? How does one address the challenges of an increasing number of aspiring applicants to such creative programs?

We will now discuss what are the different models currently used in the selection of candidates for a Design program in India.

83.4 Structure to a Design Program in India

In India, selection of candidates to the creative arts programs are administered by different bodies such as the Council of Architects (CoA) for architecture education; All India Council of Technical Education (AICTE) for engineering education and the University Grants Commissions for the education in the field of creative arts. Each of these bodies outlines their own guidelines for these programs broadly comprising of three aspects.

1. Selection of candidates for admission

What aptitude must one search for in a candidate through an appropriate mode in giving admission to a creative profession such as arts/Design/architecture?

2. During the creative program

What must be the creative learning environment of self-discovery, exploration and enquiry at the center of learning for an aspiring young trainee to prepare them for the professional world of the creative industry that one aspires to serve after their studies?

3. After graduating from the creative program

Do the training and knowledge match the demands and skill sets expected of the professional creative industry?

There is periodic review on Stage 2 of this program for revisions to the education contents. Stage 3 holds a mirror as a feedback mechanism of the real world of practice to influence updates to the education program. However, Stage 1—at entry phase of the selection process needs more serious attention and research. As a case study, in the following section, we will examine and focus on the Design programs of two of the leading schools of excellence of national importance.

83.5 Case Study on Admissions to the Design Programs' in Institutes of National Importance in India

The Government of India recognizes the Indian Institute of Technology, the National Institute of Design and the National Institute of Fashion Technology (NIFT) as institutes of national importance. They offer a wide variety of specializations in Design including the fields of industrial Design, communication Design, interaction Design, textiles and apparel Design; Design management; visual merchandizing; product Design engineering etc. Each of these leading institutions conducts their own all India entrance examinations for admissions to their Design programs.

1. Among the IITs', the all India 'Undergraduate Common Entrance Examination in Design' (UCEED) and the 'Common Entrance Examination in Design' (CEED) form the basis for selection to the Design programs offered for the undergraduate and postgraduate Design studies, respectively. The results of these examinations are also accepted among other leading institutes. The programs on offer include product Design, interaction Design, communication Design, product Design engineering etc. The postgraduate programs are offered for graduates from fine arts; all streams of engineering; architecture graduates and Design graduates.
2. The National Institute of Design (NID) conducts an all India Common Entrance Examination for its undergraduate and postgraduate programs of Design. They follow it up with 'on-campus' studio tests and interviews for the shortlisted candidates before the final selection are made. The scores of these common tests are also accepted among some of the private and public institutions.
3. The National Institute of Fashion Technology (NIFT) is the leading institute focused on training professionals to meet the requirements of the fashion industry. They offer programs in fashion Design, accessories Design and textile technology among others and conduct their own admission tests.

83.6 Admissions Protocol

For a young undergraduate aspirant, preparations begin at senior school by exploring the professional courses on offer through the different institute Web sites. How should one prepare for the admission test is an unresolved mystery. The crop of coaching centres becomes a starting point. These focus on enhancing drawing skills. The candidate is now ready—ill-prepared, half-baked. Aspirants in this state appear for the all India admissions test (UCEED/NID entrance test, NIFT entrance test for undergraduates). Similarly, the selection process for the postgraduate Design program involves:

Part A Dur. 1 hr		Part B Dur. 2hrs	
	Visualization & Sopatial ability		Drawing
	Environmental & Social Awareness		Creativity
	Analytical & logical reasoning		Communication skills
	Language and Creativity		Analytical & problem solving skills
	Design Thinking and problem Solving		Design Thinking and problem Solving
	Observation &Design sensitivity		Observation &Design sensitivity

Fig. 83.1 Examination pattern for CEED2018

Stage 1: Appearing for an All India Common Entrance Examination in Design (CEED) to achieve a minimum-qualifying cut of score. This makes them eligible to apply for the Masters' program on offer among the different institutions across the country that accepts CEED as the qualifying exam. The examination pattern for CEED, conducted in two parts, is shown in the chart (Fig. 83.1).

The type of exam includes assessment of the candidate's general awareness, creative abilities and visualization abilities. Further, the sections are divided to assess the chosen stream of Design specializations offered among the different institutes. Figure 83.2 shows data indicating applicants who appeared and those who qualified; while Figure 83.3 shows the scores procured by the top three candidates in the CEED 2018 examinations held during 2018. Only 1003 were ranked

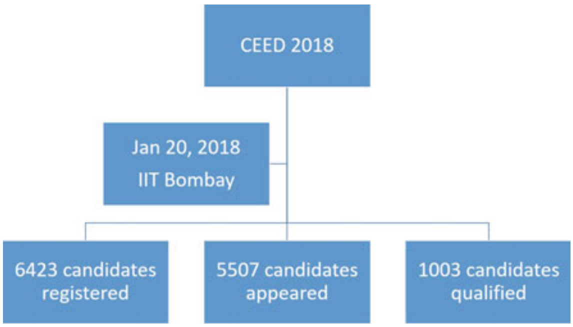

Fig. 83.2 Data on Applicants for CEED2018

CEED 2018 Ranking
1st rank score 77.53
2nd rank score 75.08
3rd rank score 71.42

Fig. 83.3 Scores procured by CEED2018 candidates

for about 400 available total seats from among 6423 who applied and 5507 candidates who appeared for the CEED examination.

Similar to the CEED applicants, during the year 2016, there were nearly 10,451 candidates who appeared for the NID entrance examination for just 100 seats on offer for the B.Des program and 9200 applicants for 275 seats for the M.Des degree program at the NID campuses.

Those candidates who have qualified the all India examination are then called for a review of their portfolio and for a personal interview. Studio test is part of the protocol that candidates undergo during the on-campus test. The selection panel reviews the test scores, the scores of the studio test and the performance of the candidate in the personal interviews. Candidates are selected based on these three assessments. This rigor in the selection process helps to select a creative pool of talented candidates.

As a case study, the protocol analysis was further undertaken to review the process of on-campus tests/interviews undertaken by candidates appearing for the aptitude test for the postgraduate Design program during the year 2014, at one of the Design schools. The applicants were graduates of the following streams: engineering; architecture; fine arts and Design.

One hundred and sixteen applicants, 94 male and 22 female, having qualified the all India CEED exam, applied to the institute for admissions and were invited to appear for the on-campus aptitude test and interview. 55 candidates had appeared, of which 47 were male and 8 female. A weightage of 15 marks for the on-campus test, another 15 marks for the personal interview and 70 marks for the CEED examination performance formed the break up for assessment for the 55 candidates who appeared for evaluation.

Based on overall performance, the candidates were ranked on merit to announce the selected 26 candidates. These included candidates from the general and the reserved categories. The complexities of ranking must be noted for its social inclusiveness. While the evaluation is based on scores marked during the test, these are subsequently normalized based on a set algorithm that factors in the economic and social class that the candidate belongs. This process makes it a fair playing making it a fair playing field of social inclusiveness. These are based on Govt. of India guidelines and are not governed by individual institute norms. An additional 6–8 candidates were kept in the standby list. Should a few of the candidates opt to reject the admissions offer, these candidates would get the offer letter of admission.

The overall summary of performance in the CEED admission test for postgraduate Design studies at this school indicated that of the 26 candidates selected, 61% were engineers and the rest 39% were architects, designers or fine arts graduates. Male to female ratio was 5:1. The number of female candidates was approximately 1/6th of the applicants of the male candidates. However, women candidates were better placed in the CEED ranking than those of the male candidates. 45% of applicants form the reserved category at this school. Considering that the percentage of reservation for candidates under reservation categories is 22% of the total intake, applicants under this category give a stiff competition for selection for admissions under the general category. This is remarkably high indicating the aspirational levels.

The CEED ranking in the range of 14–237 for men and 122–334 for the women, in the general category indicates that the overall ranking was in the encouraging midrange. However, the competition was stiffer for the selection of male candidates. The selection of the candidates for the reserved category (rank 148–696) also appeared competitive. This could be because the institute is located in the north-eastern region and it attracts candidates from a rich diversity of educated ethnic communities of the region for whom higher educational aspirations are a gateway for good employment opportunities across the country. This is encouraging and reflects high aspirations among the reserved category candidates of the region that desire to do well for themselves in their careers.

Did the CEED ranking also reflect in the 'on campus' aptitude test? How was their performance in the personal interviews? This becomes an important exercise since a lot more characteristics of personality; motivation and drive for pursuing a creative professional career become evident through the tests and the personal interviews.

These are analyzed specifically through qualitative assessment of their aptitude test. It is evident through a review of their creative concepts sketches of their inclinations for streams of specialization they pursued subsequently after their admission to the program. There is clear evidence and consistency that candidates who did well in the creative and drawing test also went on to do well in their projects during their program subsequently. Candidates with fine arts backgrounds seemed consistent and good in their drawing tests. Creativity and originality seemed however average. Candidates who showed inclination for material objects opted to also pursue the product Design stream subsequently. The candidates with architecture background, although competent in drawing and conceptual streams seemed to navigate and find their foci into the domains of usability and user experience streams.

83.7 Post-Program Phase—Review of Design Work During the Program After Admissions to IITG

Having got admitted how has their performance in the transformative phase during the two-year program?

It can be noted that the four candidates with a fine arts background continued to work in their comfort zone opting for projects in identity and branding Design. They are stronger in their conceptual abilities due to inputs in human centric Design methodologies that help them to match conceptual work with good graphic Design skills. The three architects and three designers are seen to broaden their learning framework and seem more comfortable to navigate into the domains of interaction Design and user experience Design. New emergent domains that is promising and more lucrative than the struggle that young architects face during the start of their professional architectural careers. The sixteen engineers seem to have discovered the creative space for conceptual Design work. They are willing to fail and see this as a journey in learning. They are seen to be more open and exploratory in their Design thinking abilities and in their choice of projects. These are diverse, ranging from automobile styling, product Design, experience Design etc. In some way, discovering what they wish to pursue in their careers. Not keen on placements through the formal institutional channel such as the placement office, they seek time to find their way forward on their own with willingness and courage to share uncertainties.

83.7.1 Closing Remarks on Admission Processes in Design Education in the Near Future

It is evident that there is strength in the selection process for the Design programs. It assists the candidate and the institute in a process of self-discovery of a more holistic and assimilative approach to creative learning and self-discovery. The challenge and counterpoint that goes against the process are in outputs. The number of graduates that come out from all these institutions put together would be in hundreds and this is obviously inadequate and insignificant for the real needs of inculcating an alternate culture of learning that encourages explorations in creative learning. With the empowerment of large sections of societies with technologies such as ubiquitous computing, mobile technologies, the millennium generation is being educated on open source platforms with these new technologies that are now familiar and the every day. The influences on pedagogical processes are also constantly evolving [10]. Learning on the move, MakerLabs, 3D printing processes and collaborative learning offer new experiences in education. Traditional methods of studio-based selection processes for admission to Design programs will have to go beyond the existing processes in selecting candidates with the right aptitude. This will put demand on new benchmarks to identify the skill sets required for the twenty-first century. It is time to consider experiments in new modes that focus on Design thinking; collaborative learning and mobile education will have to be looked into to usher these skill sets as fundamental and core inputs across discipline boundaries and knowledge domains. For such a large scale of fundamental transformation to education per se, it is time for Design to seriously go beyond its discipline boundary and be merged as a core approach to learning that is reflected across multidisciplines. Serious attempt is required in the Indian context to introduce Design thinking, creativity and innovation as a core input early by introducing it into the school education curriculum if upscaling and growth of this core profession has to meet challenges of demand for a large country like India. A concurrent effort at introducing Design thinking as a fundamental approach in the technical education programs in engineering education will give a big boost appropriate to meet the opportunities for enterprise and start-up for the aspiring youth of the millennium generation. Imagine that in India, even if half of a million engineers graduating from the 3000 plus engineering institutions across the country are exposed to the ‘Designerly way of thinking’, what impact it may have on its society at a time where development has to be approached in a inclusive and sustainable manner.

With the spurt in Design education schools expected to rise spectacularly in India in the coming decade, it is time education policy makers in the country urgently understand the potential that the field of Design offers for a transformative impetus required of the present education system. Ushering and reviving such an ethos of creativity and exploratory learning across our technical educational institutions needs to be seriously addressed.

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Chapter 84
Teaching Creative Design to Undergrade Engineering Students—Some Experiences

Prakash Kumar and Vikash Kumar

Abstract Engineering education, today, has changed with the evolving job requirements that demands for more than only a domain-specific knowledge. Engineers are expected to address more complex challenges of future that require knowledge from different disciplines. Also, in this era of market competition, the enterprises expect them to come up with innovative ideas to have an edge. Thus, conventional engineering education is going through a transition phase with rapidly changing technology and job demands. Acknowledging this evolving need, many technical institutes have taken the initiative to incorporate creative design education in engineering curriculum to give students a liberal, multi-disciplinary, holistic, and creative outlook for addressing complex multi-disciplinary problems. But, imparting design education to undergrads along with their engineering majors has its own practical challenges. Design education has a subjective and intuitive approach, which involves imagination, reflection, and iteration which is sharply in contrast with the objective technical engineering teaching. Hence, holding the attention and interest of students from non-design background is sometimes a tough task for the mentors. The paper aims at highlighting the problems faced by mentors while teaching design to the engineering UG students at Shiv Nadar University. Based on their experiences, the authors have put forward several insights that might help young mentors interacting with the students with non-design background.

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84.1 Introduction

Engineering education has been changing with evolving job requirements that demand having more than only a domain-specific knowledge. Today, engineers need to work on new problems that are more complex and multi-disciplinary in nature requiring knowledge from different disciplines. Also, in this era of market competition, the enterprises expect them to be more creative and innovative and generate ideas to give them an edge over competitors. Hence, traditional engineering education is going through a transition phase with rapidly changing technology and job demands, shifting from its core discipline-specific approach toward a more holistic, multi-disciplinary, and creativity-based approach. Acknowledging this evolving need, many technical institutes have taken the initiative to incorporate creative design education in engineering curriculum to give students a liberal, multi-disciplinary, holistic, and creative outlook for addressing complex multi-disciplinary challenges of future. Design Minor Program for UG engineering students at Shiv Nadar University (SNU) is one such initiative.

84.1.1 Design Minor Program

Design Minor is a program for engineering undergraduate students with non-design background where they are offered a set of 4–5 basic design courses with certain credit that have to be completed along with their major course credit. These courses belong to different domains of design, i.e., product design, visual communication, human factors. The objective of such program is to give them an overview of the field and train young minds in design thinking. This is achieved by providing a transdisciplinary environment to students from different engineering disciplines, introducing them to basics of design and engaging them in creative problem-solving through small assignments and projects. This is an important initiative to nurture critical thinking and creativity among engineering students. But, there are some practical issues related to teaching design to these students which can be owed to various discipline-specific differences between engineering and creative design.

84.1.2 Differences Between Engineering and Creative Design

Engineering is a technical dominant field with more focus on the analysis where the problems are well defined within the clear disciplinary boundaries with all constraints properly defined. There are unambiguous empirical processes which lead to only one final solution. Engineering focuses, mainly, on the technical and functional aspects of solutions like increasing technical efficiency of an engine, calculating reliability and strength of certain systems. They are hardly any considerations regarding the user and the context of use. The decisions are based on quantitative studies, and there is no scope for intuition or any kind of tacit knowledge. On the contrary, design is a user-dominant transdisciplinary field involving natural sciences, social sciences, engineering, and other disciplines with the greater focus on synthesis. It addresses ill-defined real-life problems which do not have any disciplinary boundaries with many unclear constraints. Design processes are generally iterative and unambiguous and lead to more than one equally good solution. It has the main focus on the human aspect of the solutions like aspects related to how the user will be using the solution effectively, what problems the user would be facing during operations. The decisions involved in quantitative approach as well as qualitative approach and intuition and tacit knowledge play an important role in creative problem-solving. Since there are significant differences between the two fields, there are some practical difficulties related to teaching design to these students with different expectations and aspirations. The paper presents a qualitative account of authors' experiences of interacting with UG engineering students which may help the young design educators.

84.2 Method

The paper reports a descriptive account of authors based on their interactions with 170 UG engineering students which were enrolled to the design courses under Design Minor Program or University-Wide Elective (UWE) courses between 2014 and 2018. The method used for collecting information was qualitative and was based on observations, interactions with students, and their informal feedbacks. These observations were based on interactions with students during lecture sessions as well as experiences during different assignments and group projects undertaken as the part of courses on product design, visual communication, and ergonomics. Eventually, some patterns were seen in the issues observed while teaching them. These have been summarized as the common issues observed by authors while teaching the UG students.

84.3 Issues Observed While Teaching UG Engineering Students

The main focus of design mentors for Design Minor Program is to broaden student's perspective of perceiving problems and developing a creative problem-solving attitude. But engineering students, with their prior learning experiences in the technical domain, often, have difficulties in learning and developing a creative attitude. During the product design classes, it was apparent that some students were kind of lost and not attentive. During interactions, they shared that teaching approach for design course was very different from their other engineering courses which are well defined and objective. The subjective approach in design often puzzled them. They also feel difficult to illustrate their ideas due to difficulties in drawing and sketching. They also communicated that no engineering courses warrant for out-of-the-box solutions. Engineering education trained their minds in thinking toward a single correct answer; there is a confusion regarding the multiple correct solutions approach in design. It was observed while developing concept solutions during group projects, that most of the groups developed only one solution. When asked the reason for not generating multiple solutions, the most common reply was that they felt the other concepts were not technically feasible. It took longer to convince them to bring their ideas on paper before rejecting them outright. Also, the creative design process often involves ambiguous and intuitive decision-making which is in contrast with the problem-solving process in engineering which is empirical and well defined. During projects, students need to make intuitive decisions. For example, while developing signages with the campus identity, the group decided on the form choosing elements within the campus (Fig. 84.1). Making such subjective decision is very difficult task as the process is very intuitive and ambiguous.

The multi-disciplinary approach of design also leads to difficulties during ideation and execution among students as, in engineering, they are used to work within rigid disciplinary boundaries. Hence, it appears to them as they have been taken from a stream to an ocean. Besides, design involves critical as well as creative thinking where it takes time for reflecting and coming up with a novel idea. After identifying the problem, most of the solution that engineering students come up with involved the use of sensors and some gadgets which may not be a justifiable and practical solution for the problem. For example, the project done by the student

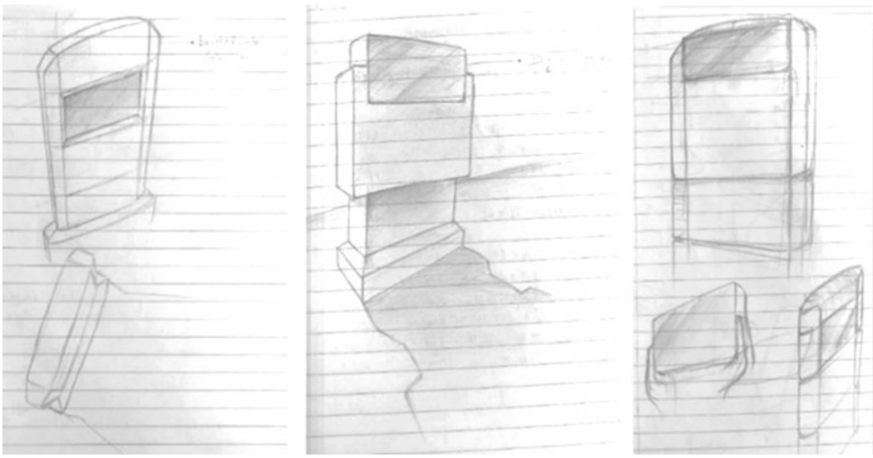

Fig. 84.1 Form generation during signage design with campus identity

Fig. 84.2 Student project for promoting handwashing habit among rural school kids through low-cost interactive tap

to promote handwashing habit among rural school kids involved the use of sensors and electronic components which required power as well as regular maintenance cost which was not sustainable (Fig. 84.2). Thus, the students had to repeat the process several times before reaching the suitable solution.

This is demotivating and frustrating for students used to quantitative problem-solving which is straightforward and fast. It leads to discontent and feeling of doing nothing fruitful. The students feel disconnected and alienated getting demotivated and frustrated due to the iterative processes. Hence, it is very important to guide them carefully through design processes and design mentors have to play a critical role in this. On the basis of their experience and insight, some suggestions have been discussed by the authors, as a mentor's perspective, in order to improve design teaching process for engineering students.

84.4 Discussion

For improving creative design learning, some insightful suggestions have been discussed below which can be divided into three broader categories, i.e., regarding the nature and content of the course, pedagogical methods, and students' progress assessment.

84.4.1 Regarding the Nature and Content of the Courses

Design Minor Program exposes engineering students to design field for the first time, and hence, the courses have to be introductory. They may be less theoretical and have a larger number of small practical problems which will give them

Fig. 84.3 A glimpse of the pottery workshop held recently at Design Studio

opportunities to observe the problems around and reflect on them. The courses may be divided into modules combining a set of similar topics with theory lectures, assignments for a better understanding of students. In addition, there should be talks, workshops, and industrial visits for providing greater exposure to design processes and developments. Small workshop on basic pottery organized recently at the department has interested not only design minor students but also other students from outside the program (Fig. 84.3).

84.4.2 Regarding Pedagogical Methods

The level of learning activities in engineering is mostly up to mid-levels of Bloom's taxonomy of learning, i.e., remembering, understanding, applying, and analyzing [9]. And there are fewer opportunities to reach the highest level, i.e., creating. Efforts should be made to reach the higher levels to have better learning. In creative design, the probability of achieving the upper level is high if certain basic considerations related to design pedagogy are implemented. These considerations could be largely beneficial for imparting any kind of creative learning.

A. **Understanding the Students**

All students are unique as in terms of their strengths and weaknesses. Every individual is creative, but some students exhibit higher creativity in their work whereas some are not so creative, as per 4-C model of creativity [8]. They have different perceptiveness, empathy, inventive disposition, etc. So, we cannot use the same approach for everyone while teaching. They have to be supported in the areas they are weak whereas their strength areas have to be exploited. Thus, they have to be treated subjectively. To decide how the individual students are to be treated, we have to know them, understand their thinking, interest, tastes, hobbies, aspiration, likes, dislike, strengths, the problem they face, etc.; this can be achieved by interacting with them while observing them during design-related tasks. In one of

Fig. 84.4 A student project, for heating cold lunch food in an easy and cheap way, involving electric circuits and components, done by mechanical students

the projects, students, mainly from the mechanical background, were interested in designing a product that involved a lot of electronic components. They had initial difficulties, but they were able to complete the project successfully as it was something that interested them (Fig. 84.4).

This also proved that the students can excel in project outside their disciplinary boundaries if it is of their interest.

B. **Create a free and friendly conducive environment**

The students, being from the non-design background, may have a lot of curiosity regarding the field of design. They might also be facing difficulties at different learning stages. If these are not addressed, they may get demotivated. They may have different new ideas with great potential. If they do not get a chance to express their ideas, they may remain shy and reluctant and eventually stop sharing their ideas and lose interest. Hence, the student should be provided with a conducive and friendly environment for speaking their mind, where they feel free to share even their wildest idea without being critically judged, put down, or ridiculed and where they have the freedom to take decisions on what and how to address an issue without any fear of failure. Since the design is heuristic, a friendly environment also enables experiential learning, where the student learns through experiences, reflects on the experience, and connects one experience to another which is very crucial for critical thinking and problem-solving, communication, collaboration, and creativity [1]. It has been observed, in every batch, that there are a significant number of students who are reluctant to speak up but they slowly open up but do excellent work if the atmosphere is lenient and friendly.

C. **Use creative methods of instruction and have some room for chaos**

The creative instructional process should be lucid and simple to lessen the cognitive load and improving the understanding of students thereby grasping greater attention [10]. The lectures should be full of common interesting examples and anecdotes with which students can relate. Use multimedia material like picture, films, documentary to illustrate facts in an interesting way. Encourage interactions, discussion, and arguments while the classes, but it should not allow to go out of control.

Devising small games or enacting plays could also make them catch the matter understand concepts easily and quickly.

D. **Take students out of classrooms**

The design is about creative problem-solving that cannot happen by just assuming certain facts and situations sitting in a classroom. They need to witness the problems themselves. If possible, they should be able to put themselves in other shoes. This will give them the actual feel of the problem as compared to the superficial assumptions generally made about a situation. They also develop empathy and sensitivity toward the conditions and challenges prevailing in society [7]. While exploring outside the class, they not only came up with new problems but also tried to solve them.

E. **Give assignments based on real-life problems that interest students**

Try to give assignment grounded in real-world situations where students have an opportunity to study, explore, and reflect on the real-world problem [2]. The purpose and objective of a particular assignment should be properly communicated before giving the assignment and made clear what is expected from the students. The students might be assigned different tasks depending on their interest and strengths. This would lead to greater freedom, interest, and ownership of the task assigned. Any idea about the assignment from students' side based on the theory taught should also be welcomed.

F. **Make people working in teams and possible with new face**

When students work alone, they may get good ideas but they tend to think in one direction or consider only in a few dimensions. If they work in a group, a new dimension emerges [11]. Also, the familiar group may have a similar way of thinking, whereas when a new set of people work together in a team, the cross-fertilization of ideas occurs and diverse and rich ideas are more probable. The teamwork must have phases of individual and collective work, respectively. This would ensure that people have greater ownership of work, and at the same time, they have room for reflecting on the work individually too. Group tasks also help in removing shyness and building trust. It was observed that when they work in a mixed group the kind of ideas generated was quite versatile.

G. **Encourage project-based learning**

Project-based learning encourages students to address the real-life problem holistically and enhances creativity [3]. Working on the project of their interest keeps them motivated and moving. Working on real-life problem warrants for a multi-disciplinary approach which enables students to identify and apply authentic connections between two or more disciplines and/or to understand essential concepts that transcend individual disciplines [6]. Hence, it presents new learning and exploring opportunities to students which keeps them engaged. Eventually, the realization of solution further boosts their confidence in problem-solving.

H. **Monitor Time for different tasks**

Though coming up with a creative idea does take more time in taking shape but minor programs, time is very limited. Many times, it so happens that project is very innovative but, because of time shortage, the students are unable to complete them. Time has to be managed at all stages of assignment and project. The time schedule of the project has to be prepared by the group and followed strictly. And an eye should always be kept on the progress of the project. For the assignment, instead of teachers, the students should decide the deadline which will create a sense of responsibility and ownership. If they are asking for an extraordinary time, then it can be reduced. During the courses, it was seen that being more lenient actually leads to delay in submission of projects.

I. **Celebrate design**

The students will only be motivated to understand and learn design when they see the power of design; i.e., what it can do and what kind of changes it can bring. This will inspire them in achieving what they want to do, using design. Hence, design achievement, as well as the latest development in the field, and new opportunities are required to be celebrated. This will make them imagine and explore the exciting things they can achieve through design.

84.4.3 About Assessment of Design Learnings

Engineering undergrads due to their prior discipline-specific experience have a great concern for grades which shifts their focus from creatively thinking and reflecting to anyhow finishing and submitting the assigned work. Hence, to ensure creative learning, the assessment strategy should aim at addressing this concern. The student should be assured that they would not be penalized even if they fail to deliver a solution, and it is their direction of thinking, effort, and engagement which they would be judged for. The assessment should not be only at the end of the task, there should be a stepwise evaluation to check if the students are properly engaged and heading in the right direction to solve the problem. The outcome may be evaluated for its originality, usefulness, meaningfulness, appropriateness, but the focus must be on their process rather than the final product. The work should be seen in terms of how they have gone deeper into your topic, both in terms of researching it and in terms of synthesizing the research. Eventually, the creative design learnings may be assessed under three broader categories, i.e., cognition (in terms of capability of selecting and analysis of relevant information, anticipating consequences, understanding and integrating knowledge from different domain), emotion and motivation (in terms of developing positive approach foster compassion, tolerance, humbleness to accept criticism, promoting teamwork and inclusivity), and behavior and action (being proactive for benefit of society at large, developing skills to observe the problem correctly, conceptualize and implementing the solution) [5].

84.5 Conclusion

The main objective of the Design Minor Program is to inculcate an aptitude for creative problem-solving among the engineering undergrads. But, due to a core technical non-design background, there are some practical issues in teaching these students which have been discussed in the paper. Based on the experiences of teaching these students, several insights have been shared which may help the design mentors in imparting knowledge to the non-design background engineering students as well as the others. There were several ways suggested that could enhance the interest of the students and facilitate the learning processes. But there are some other limitations related to this approach too. Even if the design mentors are able to build a very conducive environment for design learning, this effect would be only short-lived. It would be overshadowed by a load of their engineering-related subjects which constitute their major. Hence, they again return to the same core domain-specific knowledge environment and disciplinary boundaries. Thus, the addition of few minor design courses with core engineering curriculum may just not be good enough. Perhaps, design education needs to be integrated with engineering in such a way that students practice design as a part of engineering courses and where every engineering assignment turns out to be a creative effort with a noble cause, where engineering inputs are used to solve day-to-day problem transcending the disciplinary boundaries. Every assignment should present the scope for new innovations. The design thinking should be so carefully woven within engineering education that there is no requirement for a separate Design Minor Program. Then only can engineering meet the new evolving complex challenges of the future in a real sense.

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Chapter 85
A Gamified Model of Design Thinking for Fostering Learning in Children

Rahul Bhaumik, Apoorv Bhatt, M. C. Kumari, S. Raghu Menon and Amaresh Chakrabarti

Abstract Design thinking is a process that is used to systematically find goals, generate proposals to satisfy the goals, and develop these until satisfied; the areas of application are intended to be universal. This paper proposes a simplified model of design thinking called 'IISC' (Identify-Ideate-Select-Consolidate), a gamified version of the design thinking model called 'IISC DBox' for use by schoolchildren, and a generic framework for the assessment of gamified models of design thinking. The framework to assess the 'gamified' model, takes into account the nature of the constituent elements of the game, and also the outcomes and feedback of the players involved in the game. The assessment framework not only highlights the potential and effectiveness of the model but also throws light on the areas of its future improvement.

85.1 Introduction

Design thinking is the cognitive process from which design concepts emerge [1]. It is an iterative process which involves identifying goals (needs), generating proposals to satisfy the goals, and improving both the goals and proposals [2].

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A game is a system where players engage in an artificial conflict, defined by certain rules that result in a quantifiable outcome [3]. Gamification uses game-based mechanics, aesthetics, and thinking to engage people, motivate action, promote learning, and solve problems. Gamification considers some elements from game design and incorporates into a content that is to be learned by the player. It can be categorized into two types: structural gamification and content gamification [4]. The first type uses game elements to propel a learner through content with no alterations to the content. The second type uses game elements and game thinking to alter content to make it more 'game-like' and may involve provision of game context/activities to the content.

According to a report in 2016, India has 47 million students dropping out of school by the tenth standard [5]. Data from the National Sample Survey Office (NSSO) shows that 13 out of every 100 Indians between 5 and 29 years did not attend school or dropped out because they did not consider education necessary [6, 7]. A study conducted in a high school in Canada showed that often the students lack motivation to learn any coursework or extracurricular activity, as reflected in their poor concentration in class or boredom, which in many cases also leads to high school dropout. [8]. Students are bored because the things they are given and told to do in school are perceived as trivial and dull, making limited and narrow demands on the wide spectrum of their intelligence, capabilities, and talent [9].

The objective of this study is to develop a framework for both analysis and design of a 'gamified' model to nurture design thinking in school students.

85.2 Potential of Design Thinking in Education

Implementation of design and technology in schools was initiated from 1990 in the state schools of England and Wales for children aged between 5 and 16 years [10]. Doreen Nelson, a US-based educator, pioneered design-based learning 35 years ago that has exhibited dramatic improvements in the achievements of K-12 standard students [11]. According to Dunne [12], design activities were meant to go beyond knowledge and skill and include practical wisdom. In Indian school education system, where dropout rates are very high, a productive and creative workforce is possible only by addressing the need for innovation and creativity at a young age, preferably from the primary years [13].

Tim Brown, CEO of IDEO, states that 'design thinking' widely adopted by designers, can also be used by other individuals and groups like business organizations to foster innovation [14]. Innovation happens in three phases: 'inspiration' which is the problem or opportunity that motivates the search for solutions; 'ideation' which is the process of generating, developing, and testing ideas; and 'implementation' which leads the way for the idea to reach the market [14].

Design thinking arguably can be followed by an individual to develop a solution for problems at various levels of complexity; and in the process of doing so, the person learns as to how to solve a problem that is relevant for the learner or someone else.

85.2.1 Current State of Design Thinking Education in India

Number of design programs (graduation level and onwards) in India grew from 2 in 1960 to 15 in 2006. But the lack of mass awareness about design and research into design, and the nature of formal education system, which predominantly promotes analytical thinking, are the major obstacles in promoting design education [15]. Presently design programs in India are predominantly taught at graduate and post-graduate levels in schools like National Institute of Design, Indian Institute of Science, Indian Institutes of Technology (IITs), School of Planning and Architecture (SPAs) and other privately run institutions offering courses in various design disciplines (industrial design, communication design, fashion design, etc.) [15].

It has been observed that the instruction material primarily used for teaching design thinking is in the form of handouts, printed lecture notes, online lecture notes, etc. Besides, there are several 'design method cards,' e.g., from IDEO, SUTD, Oblique, DSKD to help designers and general enthusiasts with the process of designing. However, it is not easy for designers to obtain an overview of a card system and to decide which card system is best suited for coming up with a design solution for a particular problem [16].

85.3 Gamification of Design Thinking: The Proposed Framework

The authors have developed a design thinking model by analyzing and combining the various activities from existing models (e.g., [17–19]) with four broad generic stages, that are further divided into sub-steps (Table 85.1). The four stages are: *Identify Requirements* (involves observing habitats; empathizing and talking to people; creating a list of requirements as to what is to be achieved; and ordering these into demands and wishes), *Ideate Solutions* (involves enlisting process steps for the activities in the observed habitat; generating alternative ideas for each requirement; grouping similar ideas; and combining alternative ideas into alternative solutions), *Consolidate solutions into feasible solutions* (involves modeling solutions; analyzing these against the demands to modify them; and analyzing these against the wishes to further modify them), and *Select the most promising solution* (involves revising the list of requirement; prototyping solutions; evaluating against revised requirements; combining individual evaluations; and comparing the aggregated scores to select the best solution).

Design activities typically involve a team with multiple people in a project. Playing a game can encourage cohesiveness among players and motivate them toward a common goal, reflecting on the progress. A game that elicits a play to guide and motivate players into design thinking, in contrast to monotonically responding to a set of guidelines in a printed document, can prove more beneficial

Table 85.1 Design thinking steps in our proposed framework and their potential impact on learning objectives and subsequently deriving their favorability to the learning approaches

Learning objectives		1	2	3	4	5	6	7	8	9	10	Approach			Implications	Elements for 'gamification' content
												B	Cog	Con		
Identify problems	Observe	✓	✓	✓								H	M		Instructions to look at things from a 'new' perspective	Use of examples
	Empathize & talk to people			✓									M	H	Interaction with people/storing information in mind	Examples/motivation to shed inhibitions
	Create a list of requirements			✓	✓	✓							H		Retrieval of information in mind	Use of examples/ analogies/outliners
	Order requirements				✓	✓							H		Restructuring + retrieval of information	Analogies/organizers
Ideate solutions	Imagine process steps						✓						H	M	Recalling and organizing information in mind	Use of analogies/use of examples/storyline
	Generate alternative ideas					✓	✓	✓	✓			H	M	H	For 'new' methods, the learners can learn fundamental steps before attempting complex steps	Provision for spot practicing/use of examples/storyline
	Group similar ideas						✓						M	H	Organizing information in mind/engagement in social negotiations	Instructions for peer verification
	Combine alternate ideas for alternate solutions						✓	✓				H	M		For 'new' methods, the learners can learn fundamental steps before attempting complex steps	Provision for spot practicing/informative feedback/use of examples

(continued)

Table 85.1 (continued)

Learning objectives		1	2	3	4	5	6	7	8	9	10	Approach			Implications	Elements for 'gamification' content
												B	Cog	Con		
Consolidate solution	Model/prototype each solution							✓					M	H	Information retrieval + co-learner interactions	Analogies may be presented
	Analyze each solution against demands							✓					H	M	Information organization/ retrieval + peer negotiations	Instructions for peer negotiations
	Modify solution to resolve conflicts									✓	✓		M	H	Information retrieval + peer negotiations	Examples & analogies
	Analyze each solution against the wishes and modify them									✓	✓		H	H	Information organization/ retrieval + peer negotiations	Examples & analogies/instructions for peer negotiations
Select solution	Revise the list of requirements			✓	✓						✓			H	Social interactions + peer negotiations	Motivation for social interactions
	Model/prototype each solution and evaluate against each requirement							✓	✓	✓			H	H	Information retrieval/ restructuring + peer interactions	Analogies/examples may be presented
	Combine individual evaluations, for each solution				✓			✓	✓			H	H		Introduction of new methods/ systems	Use of examples
	Compare aggregate evaluation score									✓	✓		H		Information retrieval/ organizing	Use of examples

Legend: The ✓ symbol refers that a certain step in the design process satisfies a certain learning objective. *H* stands for 'highly' favored; *M* stands for 'moderately' favored. *1* Observe one's environment or world, *2* Perceive and become aware of the processes occurring in the environment, *3* Perceive and become aware of the social (human) processes and systems, *4* Identify relevant information in memory, *5* Store relevant information in memory, *6* Utilize stored information to respond to new circumstances in environment, *7* Respond/act to circumstances, *8* Make strategies/thumb rule for Response/action, *9* Improvise strategies for better response with respect to new circumstances, *10* Gather feedback/give self-feedback for future response (contemplate) (*B* behaviorist, *Cog* cognitivist, *Con* constructivist) for the learners. Hence, the authors thought of developing a 'gamified' version of the aforementioned design thinking model which can be played by school students.

Based on authors' analyses of the importance of incorporating design thinking in educational curriculum, using [20] as the broad basis, a set of preliminary learning objectives was formulated by the authors. Table 85.1 not only proposes the relations between design thinking steps and the proposed learning objectives, but also the importance of design thinking in enabling betterment of day-to-day living.

In order to reinforce the learning of 'learning objectives,' the designer should adopt an appropriate learning approach for a particular design thinking step and extract/ adopt suitable elements (depending upon the 'approach') to determine the structure and delivery of the instruction in a 'gamified' model (see Table 85.1). A good learning approach is one that helps communicate and transfer knowledge in the most efficient and effective manner, by combining the best of behaviorist, cognitivist, and constructivist learning approaches. This, however, depends on the content to be learned and the learner's abilities [21]. In the twentieth century, learning paradigm shifted from behaviorism through cognitivism to constructivism. Behaviorism mainly promotes learning of predefined skills; cognitivism is learning focused at learner's cognitive and mental levels; constructivism is better suited for solving ill-defined problems, by recollecting one's experiences and through social negotiations [21].

In Table 85.1, the authors have also asked a set of questions for each learning approaches against the design thinking steps to determine their favorability for adoption. To determine if the learning of a content is favored by behavioristic learning, the questions asked by the authors are [21]: *Is learning of the 'content' highly favored by conforming to predetermined standards? Is learning of the 'content' favored by repeated practice of desired responses to improve performance? Is learning favored in step-by-step process from simple to complex scenarios?* Similarly, the questions asked to determine if the learning of a content is favored by cognitivist learning are [21]: *Is learning of the content highly favored by focusing on mental associations and processes? Is learning of the content favored by mental planning, goal setting, and organizational strategies (by the learner himself) that leads to a response?* Finally, the questions to determine if the learning of a content is favored by constructivist learning [21]: *Is learning of the content highly favored by learner's activities and past experiences? Is learning favored by interacting, debating, discussing, and negotiating with other co-learners? Is learning favored by creating novel and situation specific understandings by the learner?* By asking each such question against the content to be taught (the design thinking steps in this case), the authors have decided if the teaching of the content is highly, moderately, or negligibly favored by a certain learning approach.

By combining elements from [3, 4] and also taking inputs from Table 85.1, the authors have come up with six broad parameters, which can act as a checklist to arrive at a design for a 'gamified' model for the design thinking process (as discussed in Sect. 85.3). The parameters are:

1. *Information structure and delivery*: This is the data on the content of the game (e.g., instructions, descriptions), and how it is organized, structured, and presented to the player.
2. *Response*: This comprises how the player would respond to or play the game.
3. *Supervision*: This specifies how much supervision a player needs, and in what way.
4. *Feedback*: This is provided to players to not only guide them in right direction but also to tell them how 'correct' or 'well' they have been performing actions.
5. *Evaluation*: This has two aspects—evaluation of the game and its content by the players; evaluation of the players based on their performance and outcome.
6. *Reward*: Specifies how players are rewarded, as reward is a motivational factor.

See the components column in Table 85.2 for elaboration of parameters.

Table 85.2 Evaluation of DBox against the parameters in the framework

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
1.	**Information structure and delivery**			
1.1	Formulation of Instruction/ information			
1.1.1	Instruction regarding each sub-steps in the design thinking process		G	
1.1.2	Information regarding any new methods, pertaining to any step		G	
1.1.3	Use of examples		G	
1.1.4	Use of analogies		A	Analogies would help learners make sense of what is to be learned, but are not given in some of the steps.
1.1.5	Use of a storyline	Player's characteristics (age, attitude)	P	Storyline would make the content more interesting
1.2	Sequencing information (order in which instruction/ information is delivered)			
1.2.1	Order of delivery of instruction as per design thinking process		G	

(continued)

Table 85.2 (continued)

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
1.2.2	No access to future instructions without the completion of present one		A	In the present scenario, supervision of players is required (to permit no access). Design of delivery of instructions needs a relook.
1.2.3	Access to instructions (directed as per rules):		G: Movement in a board game as per counts in a custom dice provision	Elements can be added so as to maintain curiosity in players at all levels.
1.2.4	Mode of information delivery: Material	Budget/infrastructure	Text on paper	
1.2.5	Mode of information delivery: type		Text + pictogram	Storyboard/images can be used for children
2.	**Response**			
2.1	Flow of tasks		One task per instruction card	
2.2	Nature of output for each step		Notes (text) + tables +/ drawings +/ sketches +/ prototype	
3.	**Supervision**			
3.1	Observing player's task flow	Player's characteristics (aptitude, existing learning, personality)	Required for participants with no serious aptitude	
3.2	Tutoring required	Existing learning	A: Required for new methods/ definition	Content can be more detailed/ self-explanatory so as to cater to novice students.
3.3	Directions/cues required	Player's characteristics	Not likely	
3.4	Choice for supervision		Not given to students	Choice can be provided for more mature student groups
4.	**Feedback**			
4.1	Timing of feedback		Varies; depends on players call	
4.2	Type		G: Creativeness N/A: directional	
4.3	Source of feedback		G: Mentors A: room for self-feedback	Provision for self-feedback should be given to reflect upon players actions
4.5	Medium		verbal	

(continued)

Table 85.2 (continued)

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
5.	**Evaluation**			
5.1	Time taken to comprehend instruction	Player's existing learning, information structuring	Varied from 2 min to more than 5 min	
5.1.2	Additional/mentor help required to comprehend instruction	Players existing learning	Yes (in case of new content)	
5.1.3	Player's feedback (based on NASA Task Load Index [22], and system usability scale [23])	Mental, physical, temporal demand, performance, effort, frustration; interesting/curiosity	N/A	Feedback worksheet should be provided to revisit design of content + delivery
5.2.1	Time taken by player to complete a step, level of the whole game	Depends on nature of step + student's ability	Whole game: 4–5 h min	
5.2.2	Difference between the nature of desired output & nature of actual output		Large difference not prevalent	
5.2.3	Relevance of the final output		depends	
6.	**Reward system**			
6.1	Reward in terms of successful completion of the steps		A	
6.2	Rewards in terms of a 'successful' outcome		G	
6.3	Nature of reward		Verbal appreciation	Rewards in terms of physical/virtual coin/ points can be provided to motivate the players through the process

Legend: '*G*,' '*A*,' and '*P*' indicates that IISC DBox fared 'Good enough,' 'Average,' and 'Poor' respectively against the listed parameters. *N/A* not available

85.4 IISC DBox

The gamification model and learning approaches identified have been combined, and a new game was designed by the authors for the purpose of use for design thinking education for children. 'IISC DBox' is a self-contained game for supporting design thinking and design-led innovation. The word 'IISC' is an acronym for 'Identify-Ideate-Select-Consolidate'—the four major steps of design thinking in our model—so that a player can employ design thinking in order to internalize innovation. 'IISC' is also an acronym for 'IISc Innovation Support for Children,' where 'IISc' is the acronym commonly used for **I**ndian **I**nstitute of **Sc**ience, Bangalore. The game is adaptable to be played at multiple levels of depth and complexity, allowing it to be tuned to various levels of formal education at schools, colleges, and university programs. As a person or a team plays the game, it should train them in design thinking, in the process opening them up to the variety of problems people face as well as how their knowledge from other areas of the education program can be blended with their creativity to help solve these problems. Further, the process should encourage both thinking and doing, seeing these as complementary skills in real-life problem finding and solving.

IISC DBox consists of six major components—level boards, instruction cards, a customized dice, a marker coin, an evaluation sheet, and a feedback sheet.

(1) *Level boards*: There are four level boards in the game pertaining to the four levels of the design thinking process, as mentioned in Sect. 85.3. Each board has 16 positions through which a coin would be traversed by a player. Each position on a board has a color code and a logo. The logos are indicative of the sub-steps of that level of design thinking.
(2) *Instruction cards*: These elaborate on the sub-steps of the design thinking process. The description bears instructions for the players, along with examples or analogies, thus educating players the process. Each card has a color coding and a logo on one side (matching those in corresponding positions of the level board) and text with instructions on the other. The game can have a total of 16–64 cards, depending on the version for less or more experienced players.
(3) *Customized dice*: The dice has four black and two white faces (i.e., a random number generator), which is used to guide motion of the coin along a black or a white pathway. The pathways connect individual positions on the boards. When a player gets a black face on the dice, she can move along a 'black' path, leading to another position on the board, drawing another instruction card, and so on.
(4) *Marker coin*: The coin holds the position of the player on the level board; its motion depends on the dice roll and the availability of pathways on the board. The goal of the player is to traverse each board, while playing the maximum number of instruction cards and maximize the points scored in these steps.
(5) *Evaluation sheet*: This document contains a questionnaire for evaluators to evaluate the performance of the players, after the game is completed.
(6) *Feedback sheet*: A questionnaire the players fill to document how they performed, and difficulties faced; this is used to improve the game in later versions.
(7) *Miscellaneous items*: Include sketchbooks, worksheets with guidelines on which the players document outcomes from the design thinking steps.

The rules of the games are as follows. Each player keeps a marker coin at the start position of the first level board. The player then rolls the customized dice. Depending on the color on the top face of the dice, the player moves the coin along the same colored path, leading to another position. Based on the graphics printed on a position, the player takes out an instruction card, bearing the same graphic, from a set of cards. The player carries out the task described by the instructions on the card drawn and fills up a worksheet with notes, sketches, and calculations etc., as outcomes from the tasks. After the worksheet is filled, the player rolls the dice again and moves the marker coin along a ‘legal’ path to the next position. The player continues the moves and associated tasks till the end of the level board is reached. After the finishing the first level board, the player starts the same process for the next level board, till the whole game is finished.

The game is to be supervised by a mentor. The mentor’s role is to primarily supervise the player’s activity and assist them if they face any problems. The mentor’s role is limited to provide explanations of the steps if asked’ and is not meant to help with the tasks or solutions for the players or propose mentor’s ideas to the students.

85.5 Evaluation of Proposed Design Thinking Model

The first version of IISC DBox was tested at a school in Bangalore in July 2017. About 40 students, divided into 6 groups, from standards 6 to 12 played the game. Each group was composed of students belonging to adjacent standards, in three categories: standards 11–12, standards 8–10, and standards 6–8. No student had prior training in design thinking or methods. Each group was assigned one mentor for supervision. Within a stipulated time of 5–6 h, each group played the game comprising 16 steps and developed a design prototype for solving a problem they identified. The groups observed environments within the school campus (e.g., drinking water area, library, classroom) and generated design solutions. Some examples of the design solutions arrived at are, a stepped water disposal platform to accommodate variable heights of students, increasing seating capacity in their library with enhanced privacy within the same area (Fig. 85.1), etc.

Analysis of IISC DBox 1.0 (the first version of DBox), against the parameters in the framework, is listed in Table 85.2.

Fig. 85.1 Schoolchildren playing IISC Dbox

85.6 Effectiveness and Limitations of IISC DBox

IISC DBox has been reasonably successful in taking the tools and methods of design to students and individuals with little or no prior exposure to design thinking. Since the instructions for the design thinking are modularized into cards and the flow of instructions is guided by the level boards, IISC DBox seems to have the potential for supporting play by a wide range of learners, and at any place. Consolidation of the components of IISC DBox in a kit makes it portable. Playing IISC DBox seems to be a recreational activity for a player enabling an active, self-learning process.

The first version of IISC DBox has several limitations that need to be addressed for a more experiential play and more effective learning. In its current form, the language in the instructional cards is less suited to the general learner. Some of the methods proved to be too technical and complex for the students at the lower standards. Consequently, the role of the mentor transcended from that of a supervisor to more of a tutor. It proved tiring for the players to complete the entire process at a single stretch of time. The game steps appeared more predictable at later levels, but the content of the cards retained the players' interest.

85.6.1 Potential Improvements to IISC DBox 1.0

The next version of IISC DBox could be designed with a personalized storyline for the content so as to make experience specialized for the players. To feel like being an integral part of the game, the players should have an option to choose their avatar. The language in the instruction cards should be simpler, and even vernacular to be more understandable even to novice students. The instruction cards should provide more examples and analogies, to help players internalize design thinking concepts. To check for the overall quality of the output, evaluation should be done at the end of each level. To motivate users till the end of the game, tangible rewards can be given to players based on their performance. These improvements should help IISC DBox transcend from its current, structural level to that of content gamification.

85.7 Conclusions and Future Work

For learning design thinking and methods, it is important for the learner to not only know the overall philosophy behind design thinking but also the right tools and methods, and necessary information for facilitating the design process. A 'gamified' version of design thinking model presented in this paper, aimed at teaching design thinking to schoolchildren, engaged students to learn and understand design thinking in a step-by-step manner. The evaluation carried out demonstrates there is room for improvement for IISc Dbox. An online version of the game can avoid physical presence of a mentor, and the game could be monitored distantly and has also the potential to make it accessible to rural and remote areas through Internet. The gamification model of teaching could be extended, with appropriate modifications, for other topics as well, where it is necessary to train the learners a 'specific way of thinking and doing things.'

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