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

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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 *D*1 → *D*2 → *D*3 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 *D*2 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 *D*2 in between, or that *D*1 and *D*2 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 *D*2. 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 *D*2, 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 *D*3 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 (*D*1); the realisation that the *D*1 stage being important has only begun to get its importance. The *D*2 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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