Advances in Intelligent Systems and Computing 785

Salman Nazir
Anna-Maria Teperi
Aleksandra Polak-Sopińska *Editors*

Advances in Human Factors in Training, Education, and Learning Sciences

Proceedings of the AHFE 2018 International Conference on Human Factors in Training, Education, and Learning Sciences, July 21–25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA

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Editors
Salman Nazir
Institute of Maritime Operations
University College of Southeast Norway
Borre, Norway

Anna-Maria Teperi
Safety Solutions
Finnish Institute of Occupational Health
Helsinki, Finland

Aleksandra Polak-Sopińska
Department of Production Management and Logistics, Faculty of Management and Production Engineering
Lodz University of Technology
Lodz, Poland

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9th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences

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Preface

This book provides researchers and practitioners a forum to share research and best practices in the application of human factors to training, education, and learning sciences. Just as human factors have been applied to hardware, software, and the built environment, there is now a growing interest in the optimal design of training, education, and learning experiences. Principles of behavioral and cognitive science are extremely relevant to the design of instructional content and the effective application of technology to deliver the appropriate learning experience. These principles and best practices are important in corporate, higher education, and military training environments.

This book also aims to share and transfer not just knowledge, learning experiences, and best training approaches that is of real value in practical terms; value that can help leaders ensure their organizations stays ahead of the competition through continued innovation, strong competitive advantage, and inspired leadership.

This book is organized into five sections that contain the following subject areas:

I. The Design of Learning Experience
II. Learning Strategies and Future of Educational Technology
III. Scientific Concepts in Educational Science
IV. Education in Medicine, Safety and Rehabilitation
V. Technology-Based Training

Each section contains research papers that have been reviewed by members of the International Editorial Board. Each section contains research papers that have been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation go to the board members as listed below:

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Anna-Maria Teperi
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The original version of the book was revised:
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Contents

The Design of Learning Experience

Computer Supported Collaborative Learning as an Intervention for Maritime Education and Training

Amit Sharma[1], Salman Nazir[1(✉)], Astrid Camilla Wiig[1], Charlott Sellberg[2], Marius Imset[1], and Steven Mallam[1]

[1] Training and Assessment Research Group, Department of Maritime Operations, University College of Southeast Norway, Porsgrunn, Norway
{Amit.Sharma,Salman.Nazir,Camilla.Wiig,Marius.Imset, Steven.Mallam}@usn.no

[2] Unit for Pedagogical Development and Interactive Learning, University of Gothenburg, Gothenburg, Sweden
Charlott.Sellberg@gu.se

Abstract. Maritime domain is one of the most high-risk industry and it predominantly employs simulator training as a means to train the prospective operators. Maritime instructors need to train students who will become future sharp end operators and interact in highly safety critical environment. One of the goals of maritime education is therefore to create relevant learning activities among the trainees which will help them not only to learn the highly contextualized/situated knowledge of work settings but who are able to work together in team demonstrating qualities such as critical thinking and leadership. Educational frameworks that take into account the unique nature of maritime domain are therefore needed to be identified. Sociocultural perspectives suggests that learning is situated in communities of practice. In order to study how people learn in practice, it is necessary to study how individuals interact with other members and the different mediational tools that are at their disposal for engagement in specific activities. In this exploratory study, we analyze the maritime simulator training through the lens of sociocultural perspective and propose computer supported collaborative learning as an intervention for maritime education and training. We describe the salient characteristics of collaborative learning and its relevance for maritime education and computer supported training. An observation study was carried out at a maritime simulator training facility. The aim is to better understand/explore the complexities of maritime simulator training and reflect on how the collaborative learning approach can be better used to support the connections of simulated learning activities and its relevance in real life maritime operations.

Keywords: Sociocultural learning theory · Maritime education
Simulator training · Computer supported collaborative learning

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1 Introduction

High risk industries such as maritime, function in a relatively closed social environment. In the sense that the knowledge and skills required to undertake maritime operations are very specific and require effective transfer not only between teacher and trainee but between the trainee and its peers as well. Traditionally, these specific skills are acquired by trainee by spending time at the ship itself and gaining experience before being deemed competent enough to undertake the operations [1]. However, the trainee needs to learn basic theoretical concepts in the classroom along with undergoing a number of different simulator exercises to better understand technical intricacies, acquire bench line competency before going for onsite training and interacting with complex technical systems. Further, the trainee is expected to translate this conceptual understanding into practice when performing routine as well as critical tasks. The training of today's seafarer is challenging with respect to balancing the vocational and academic aspects of education [2]. There has been limited application of pedagogical interventions in the context of Maritime Education and Training (MET) [3]. The maritime education and training institutions also need to develop curriculum and learning strategies which can better utilize the technological changes being introduced in the teaching environments and integrate recent and classical pedagogical theories [4, 5]. Sociocultural learning theories and the pedagogical interventions developed utilizing computer supported collaborative learning strategies presents an interesting avenue of application to enhance simulator training in MET [6].

The Standards of Training, Certification and Watch keeping (STCW) regulations developed by the International Maritime Organization (IMO) lists down the competencies and skills the seafarer should possess. The STCW with its latest 2010 Manila amendments has emphasized the development of non-technical skills along with regular technical skills for the maritime operators [7]. Non-technical skills can be termed as the social and cognitive skills which complement the technical skills of an operator [8]. Recent studies have argued that collaborative approach to learning leads to dual effect in terms of social and cognitive gains [9]. Traditional view of training is concerned with the individual cognitive development of the trainee [10, 11]. However, over the recent decades, training is also being viewed as a participatory process where it is desired that the trainees have more dialogue and collaboration in learning [12]. Collaboration is identified as one of the key competences required in the Norwegian academic schools of the future and a key 21st century skill to possess [13–15].

In the learning sciences, new forms of educational practices have motivated novel research perspectives. For example, from teacher-centered instructions towards dialogic approaches focusing on student collaboration with technologies as mediational means to support meaning making and learning [11]. Computer Supported Collaborative Learning (CSCL) is one of the fields of research that emerged to address these technological and educational changes. There has been growing corpus of CSCL studies over the last decades that are concerned with how technology enters into collaborative work and learning activities, and to explore the complexity of human-technology interactions as they naturally occur in the context of real settings. Theories and perspectives employed in CSCL include social psychology, situated learning, activity theory, ethnomethodology, situated action as well as distributed cognition [16]. The common focus of above theories and perspectives is on the socio-historical and cultural aspects of learning and an aim to understand language, culture, interaction and other aspects of the social setting [17]. With introduction and ineludible use of modern technology in the traditional classroom settings, it has become imperative to analyze its impact on learning process and leverage the benefits to the learning goals [18].

In this paper, we highlight relevant concepts associated with CSCL and discuss an observation carried out in a maritime simulator exercise to better understand the current practices and identify avenues of further improvement in such settings.

2 Context and Literature Review

Maritime industry, just like other high risk industries predominantly employ simulators for training the operators. Simulator training occur in learning environments where instructors and students interact with simulators as mediational means. The aim of simulator based training is to enhance students learning so that they can use their knowledge and skills from the simulations as relevant and accurate resources in real-life maritime contexts. Simulator training while constituting an important part in training and assessment of maritime operators, lack sufficient empirical studies related to instructional practices [10]. There have been recent studies analyzing the maritime simulator settings using socio-cultural theories and situated learning. Studies carried out by Hontvedt et al. [6, 19] highlight the intricate relationship between simulator technologies and learning and point out the importance of instructional design. The instructor plays an important role in aligning the use of simulation to curricular objectives and to student needs. Hontvedt's work, as well as Sellberg's studies [7, 20, 21] highlight the role of the instructor in simulator exercises, in particular, how learning outcomes during simulator exercise depend upon instructor's ability to recognize the learning objectives with the ongoing activities. While the above mentioned studies have addressed important aspects of learning in simulators using socio-cultural perspectives, the analysis at group level and student to student interaction remains unexplored.

Simulation based learning is often termed as a basic form of CSCL [22, 23]. Central to the concepts of CSCL is the notion of meaning meaking as a social activity. Since, most of the bridge navigation involves small group of navigators (2 - 4), insights into the group level interaction, role negotiation and meaning making in simulated sequences can be of immense importance and act as an input for training of the navigators [24]. Prior research in CSCL has indicated that important learning gains occur at the group level [25]. The navigation skill set is traditionally learned by apprenticeship in ship and certain knowledge is internalized by the trainees but there are certain tasks in navigation that are too complex to be internalized by the individual [26]. Stahl states that Group cognition "involves meaning making and interpretation; it requires a new scientific paradigm, replacing mechanistic causal notions of statistical results under reproducible conditions with a notion of mediation under unique situations." [27].

Some of the most critical operations in maritime domain are handled at group level. Consequently, group level analysis and insights it can give is vital to maritime research.

Similarly, CSCL community has expressed the need to observe and analyze the interaction in small group settings or dyads [28]. Therefore, group level research using CSCL framework in maritime simulator settings present an interesting and synergistic opportunity to advance knowledge. Figure 1 below presents an example of complex task of navigation undertaken by group cognition.

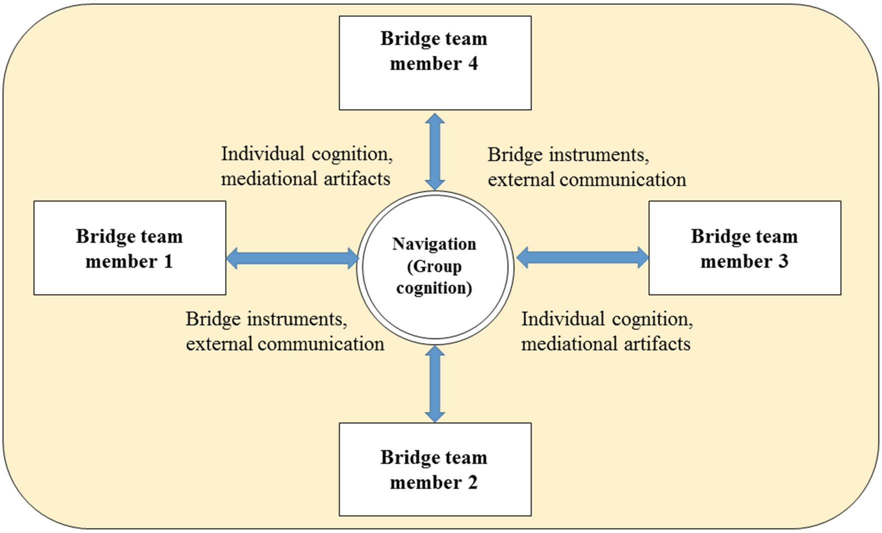

Fig. 1. Navigation undertaken by group cognition, the task is deemed complex for individual cognition

3 Observation During Maritime Simulator Exercise

The first author participated in a simulator exercise conducted at a maritime training facility located at a university college in Norway. The simulation exercise was part of study model for the Bachelor of nautical science program offered at the university college. The program is designed to provide theoretical education level required for Master Mariner certification and in accordance with chapter A-II/2 of the STCW convention. The exercise was conducted by 2 instructors and a total of 12 second year students participated in the simulator exercise. Simulation exercises form a part of their training of the navigation in addition to classroom lectures, instructions and assignments. The 12 students were divided into 4 groups with 3 members each. The training session that followed was organized into three different phases: (1) briefing (2) exercise scenario and (3) debriefing, an organization that is regularly made to make the most of the simulator training exercises [21].

The maritime training facility has four different bridge simulators which replicate the bridge of a merchant ship. The exercises are conducted in such a manner that all students in different simulators can take part of same navigation scenario concurrently. Over the course of the program students are exposed to 80 such scenarios covering various ports and straits spanning different parts of the globe to ensure optimum exposure to traffic scenarios encountered by navigators working on ships engaged in worldwide trade. The execution of the simulation exercise is done by the instructors located in the monitoring/control station with multiple screens for obtaining the video feedback from each simulator station as well as screens for planning and controlling the simulation exercise itself. The training facility has an instruction/briefing room where conventional analogue tools such as whiteboard are present along with overhead projector to facilitate Microsoft Power Point© (PPT) and video playbacks of the exercises. Figure 2 provides a schematic layout of simulator training facility.

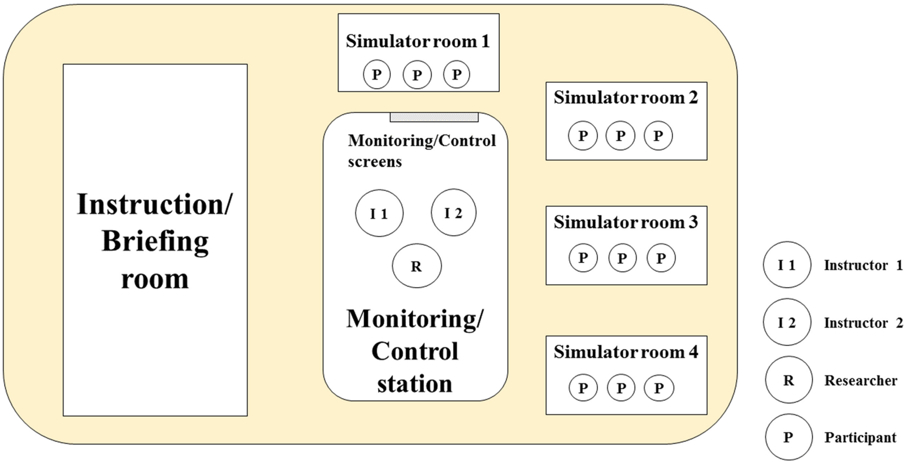

Fig. 2. Schematic layout of simulator training facility

The students were introduced to the simulation scenario by the instructors and were given a general description of the activity. This was followed up by detailed briefing where the navigation task was explained in detail along with guidelines to be followed. The students were later assigned to different simulator room with full mission bridge simulators. The main goal of the exercise was to navigate their ship from Bergen port to pilot station. Prior to the exercise, the students had already planned the passage and brought their prepared routes in USBs which were loaded in their respective simulator station. The simulation exercise was meant for the students to practice and understand the aspects of passage planning and navigation for which they received instructions earlier. The instructors communicated to the students through the control room with video displays of each simulator room. The whole exercise lasted about 3 h with 30 min of briefing and debriefing session respectively and 2 h of exercise scenario.

Figure 3 below represents the timeline associated with the three phases in the simulator exercise.

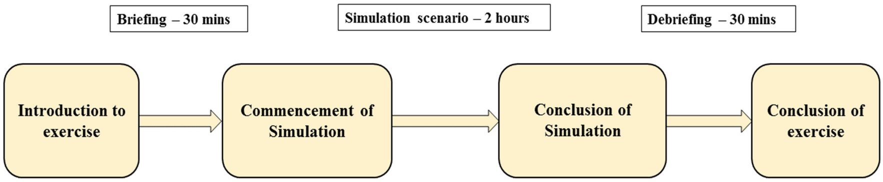

Fig. 3. Timeline of events in simulation exercise

The observer was situated in the same control room to facilitate a global view and provide minimum interference with the main exercise. The observer had no interaction with the students and occasional interaction in form of queries for clarification to the instructors. The aim of the observation was to identify avenues during the exercise where further analysis can be undertaken with CSCL frameworks.

4 Preliminary Findings

During the briefing, the students were assigned the task to navigate their ship from berth to pilot point at Bergen port. All the relevant information regarding weather, traffic and reporting requirements were communicated by the instructors. The instructor explained that each team consists of helmsman, assisting officer and captain. The member of the teams remain fixed but the students change their roles to get exposed to different duties over the course of their study [6].

After the briefing ended the students proceeded towards their respective simulator stations and initiated preparation for the voyage by filling checklists. When commencing the simulation, the instructors manned the control stations where they could track the progress of all four ships and began introducing random ships as part of traffic in scenario. The students called the instructors in the radio following closed-loop format regularly used for radio communication in high-risk domains [29]. The role of ship or Vessel Traffic System (VTS) in simulation exercise was played by the instructors. The instructors introduced weather variations, traffic fluctuations and unexpected emergencies during the exercise. This was also followed up by extra communication to the bridge done by the instructors assuming the role of different crew members and alternating between asking information to sometimes seemingly irrelevant communication to divert the attention of bridge team. The primary aim was to replicate the complex scenario of navigating a ship with the need to address multiple conflicting goals. The students were expected to operate in co-operation and divide the tasks between themselves thus providing good opportunity in training for resource management. It was noted that while the students were being assessed by the instructors for their collective awareness, knowledge of regulations and joint work for the undergoing exercise, there presents an interesting opportunity to analyze how the interaction and dialogue collaboratively builds up knowledge to collectively achieve more function than each of them would individually. It would be worth further pursuing whether such exercises in maritime simulator offer opportunities of collaboration in addition to co-operation in tasks.

The simulation exercise lasted about 2 h after which the instructors announced the termination of exercise. It was followed by detailed debriefing by the instructors where the whole group inspected the log book of students for entries and played back the exercise and explained as well as quizzed students on appropriate action to be taken at different legs of their voyage. Instructors also went individually to each group to discuss before addressing them all in common by play backing the exercise videos. After the session ended, instructors also shared the evaluation criteria for students. The instructors communicated that although they are satisfied by the depth of evaluation, it sometimes becomes difficult to separate grades of student because the criteria is designed as such which leaves less to separate students' knowledge to a greater degree. Further, there is currently no framework to evaluate the collaborative aspects of the tasks in simulator exercise.

5 Discussion

Several comments can be made regarding the execution of maritime simulator exercise, learning objectives and assessment of learning. As mentioned earlier, simulation exercise in usually divided into three phases: Briefing, Exercise scenario and Debriefing. Each phase offering different opportunities for learning and reflection of the students. Figure 4 represents the three phases and different activities performed by students. The purpose of first phase i.e. briefing, is to serve as introduction to the exercise. Here the students receive general instructions pertaining to the exercise scenario and their expected actions. The instructions received by the students are general in nature as they are dependent on the scenario of which students relatively unaware in respect to expected contingencies [21]. However, at this phase the roles between the group members are

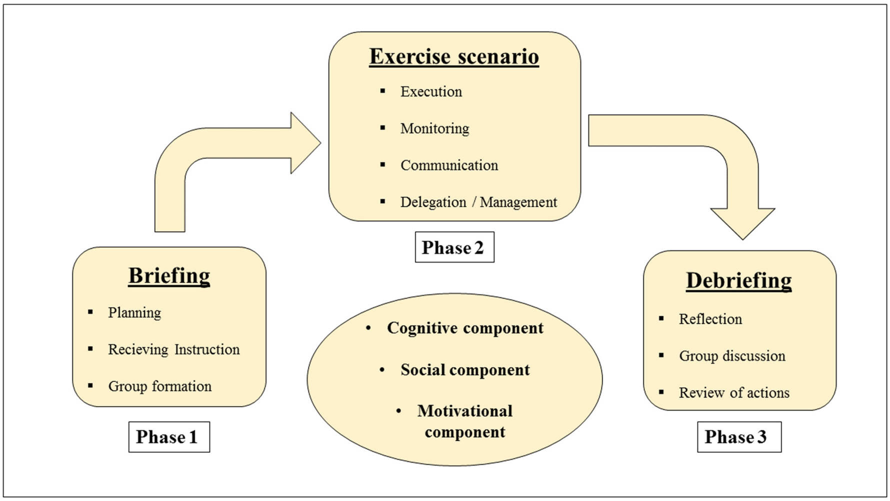

Fig. 4. Different tasks undertaken in three phases by students and three dimensions which can be analyzed in these phases.

also discussed and preparation towards the exercise scenario is undertaken. Therefore, this phase presents an opportunity to interpret and discuss the received instructions in light of the individual and collective goals. Learning in this phase can become collaborative if the students are given the opportunity to explain their approach towards the planning and learn about their peer's approach. Further, as stated earlier, CSCL provides opportunity for more outcomes rather than just cognitive. More can be known about learning outcomes and the formation of group dynamics if the group is analyzed for social cohesion and motivational aspect [30]. Prior research has indicated three major outcomes or components for CL namely: cognitive, motivational and social [30, 31].

The second phase, i.e. exercise scenario presents an opportunity to capture group cognition in action where members in the group are engaged to solve complex challenges associated with scenario. In order to further understand how the groups are executing such tasks it would be necessary to perform analysis of group discourse during simulator exercise sessions. To illustrate this point it is important to state that the nature of group cognition attributes the development of knowledge through a sequence of expressions and the final product cannot be attributed to single individual's prior mental representation [32]. For example, much of the navigation is performed by a series of interaction between the bridge members. The helmsman, assisting officer and captain each respond or pose query to each other regarding various parameters related to navigation. Stahl [26] argued that "fine grained analysis of discourse can reveal group cognitive processes of communication and coordination - but also of argumentation, deduction, problem solving, explanation etc.".

The third and final phase during simulator exercise is perhaps most important as well as under researched in maritime simulator settings in general [6, 21]. Debriefing in simulator exercise provides opportunity for group reflection and identification of corrective measures. Instructors can employ a variety of mediational tools to highlight the performance of groups and offer feedback. However, debriefing should also provide sufficient opportunity between the peers to evaluate their individual actions as well as that of group. Sellberg [21] has argued that usually the debriefing is carried out in such a manner by the instructors to direct it towards assessment and feedback rather than discussion and self-reflection within group.

The present study provides an initial identification of some of the arenas to explore further in the design and execution of maritime simulator exercises, however these findings and suggestions are preliminary. In our ongoing collaboration, we are exploring ways to extend the application of CSCL frameworks in the training of maritime operators in simulators to provide richer description of how groups in such settings construct knowledge and how it can be assessed.

6 Conclusion

In this position paper, we have argued for novel approaches for training of students engaged in maritime simulator exercises using frameworks offered by CSCL research. Our argument here for socio-cultural perspectives is to provide complimentary methods for the analysis of learning occurring in maritime simulator settings. Further empirical research is needed to rigorously analyze the mechanisms that lead to effective learning in such settings.

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Participant Training for a Flight Test Evaluation of Interval Management

Roy Roper[1], Brian Baxley[1], Kurt Swieringa[1], and Clay Hubbs[2](✉)

[1] National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA
{roy.d.roper,brian.t.baxley,kurt.a.swieringa}@nasa.gov
[2] All Aspect Aerospace Innovations, LLC, Parker, CO, USA
clay.hubbs@aaainnovate.com

Abstract. Interval Management is a concept designed to be used by air traffic controllers and flight crews to more efficiently and precisely manage inter-aircraft spacing. NASA, in cooperation with Boeing, Honeywell, and United Airlines, tested an avionics prototype onboard flight test aircraft. A critical need was identified to train the pilots participating in the flight test prior to the first flight. This paper documents the flight training regimen that successfully trained the pilots on the Interval Management concepts and flight crew procedures and suggests potential improvements to future training regimens for industry use.

Keywords: Interval Management · Pilot training · Cockpit procedures Flight test

1 Introduction

On January 1, 2020, the Federal Aviation Administration (FAA) mandate for Automatic Dependent Surveillance-Broadcast (ADS-B) equipage on aircraft operating within most U.S. airspace will take effect. Those operators equipped to meet the requirements of 14 CFR 91.225 and 91.227 will broadcast aircraft state information, allowing a receiver unit onboard an aircraft to utilize information from other participating aircraft. The capstone flight test of the NASA Air Traffic Management Technology Demonstration (ATD-1) conducted in central and eastern Washington State in early 2017 used ADS-B data to perform Interval Management (IM) spacing operations with three aircraft. Speed control directed by a Flight Deck-based IM (FIM) avionics prototype allowed pilots to achieve or maintain a precise time or distance behind a preceding aircraft. In order to test the FIM avionics prototype, a United Boeing 737-900 (B737), Honeywell Boeing 757-200 (B757), and Honeywell Falcon 900 conducted numerous arrival operations into Grant County Airport, WA.

The ATD-1 research activity consisted of three NASA developed technologies expected for the Next Generation Air Transportation System, or NextGen, airspace environment. Two of the components were ground-based for air traffic control (ATC), consisting of the Controller-Managed Spacing decision support tool and the Traffic Management Advisor and Terminal Metering Scheduler [1–3]. Both enable increased use of performance-based navigation procedures. The third component, FIM, was hosted

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onboard an aircraft and allowed pilots of that vehicle to set a specific time or distance interval (e.g., 94 s spacing or 12 NM spacing) from a preceding aircraft on the same or different route, conforming to that goal by a point common to both aircraft. To test the robustness of the system, the flight test examined how well the algorithm managed to reduce the error from a predetermined time or distance goal. For example, if two aircraft were separated by 150 s and the spacing goal was set at 180 s, one could see how well the algorithm eliminated the 30 s of error. The first aircraft was the Target aircraft, while the second vehicle, known as the Ownship, performed the IM operation. In this example, the spacing algorithm calculates an appropriate slower speed based on the position of the two aircraft and arrival procedures they are flying to slow the FIM-equipped Ownship aircraft and create 30 s of additional space between the two vehicles. For the flight test, two pairs of vehicles were used to observe intermeshed IM operations. The first pair was the Falcon 900 typically followed by the B757. The second pair was the same B757 followed by the B737. Both the B757 and the B737 were similarly equipped and could execute IM operations, and therefore could be interchanged as needed between the second and third positions.

There were two fundamental goals of the training: flight crew procedures to conduct the operation, and correct aircraft positioning when setting up each scenario. The first goal was to give the pilot experience with the prototype avionics to correctly and efficiently enter information, and also manage the aircraft's airspeed and vertical path while conducting the IM operation. The intent of this goal was to reduce the distraction from normal flight duties and minimize the impact to pilot workload during high-task periods. Simulation was used to allow pilots to practice operating the FIM avionics. The participating pilots, using unfamiliar multi-step software for a new airspace procedure, faced considerable learning and operability hurdles to achieve proficiency. During the training activity, the test pilots had to familiarize themselves with a new airspace, the FIM prototype, and the flight test procedures which included four types of IM clearances [4].

For the second goal, since the ground-based components were not evaluated as part of this flight test, the pilots, flight test director (FTD), and ATC had to work together to precisely and efficiently position all three aircraft for each test run. The aircraft had to be correctly positioned so that the spacing interval between the Target and Ownship aircraft resulted in the desired spacing error, a process which ultimately required two stages of refinement. Multiple test runs were planned for each flight test day with each aircraft potentially moving to a new start position after each run, meaning travel lengths from airport to start position would vary from run to run. Correct coordination was required to minimize inefficiencies due to time spent positioning aircraft. During the development process, a further need was identified – for the pilots and FTD to train together as part of an integrated team. The FTD was expected to be the coordinator for aircraft positioning and would be alongside NASA experts during the flight test. Due to the complex and challenging nature of positioning the aircraft for the next scenario while also entering the FIM data, the crew and FTD were trained as a team with special emphasis on Crew Resource Management specific to the flight test. The communication used between pilots and the flight test director greatly simplified the management of duties and created a realistic atmosphere from which both could train for the flight test.

2 Background

In order to ensure development of the proper skillset, NASA created a product that engaged the learner in a simple-to-learn and satisfying way. Research by De Cino [5] states, "Complex technology systems that are difficult to master and use, often create problems of usability for system users. User experience and satisfaction with the technology is partly a function of the learnability of the system, and directly affects the student during the training process." Since every person learns differently, a diversified stepwise training regimen was developed as the best means to educate and ensure transfer of knowledge for the majority of pilots. Each step was designed to train data entry and operation of the software in some incremental way while maintaining an effective learning experience. Research by Bell and Koslowski [6] describes several key features of learning which were desirable training attributes for both this activity and future experiments.

3 Training Methodology

As stated previously, a multi-tiered, incremental approach was used to prepare the pilots participating in the flight test for the next, more complex phase of training. This training regimen consisted of three steps: computer-based training (CBT), classroom training, and simulator training. Since the acquisition of basic concepts results from repeated exposure, the FIM prototype display was included in every learning exercise. The computer-based training and user guide for the prototype was initially provided to participants ahead of training at NASA Langley Research Center (LaRC). It contained reading material, video, and was implemented with a guided touch-screen interface. Later instruction occurred in a classroom setting using interactive training. Then fully immersive training was given using flight simulators to conduct simulated scenarios in the flight test airspace. This was followed by extensive debriefs where problems and irregularities were discussed and corrected.

Prior to training the pilots participating in the flight test, two separate groups of four pilots each were recruited for development of the training program and scenarios flown in the simulators. Each group consisted of two crews qualified to fly the B737 or B757. Each development crew was made up of a pilot with previous FIM research experience and one without. The groups were each staggered by two weeks for two sessions, allowing researchers to observe learning retention over a one-month period between each test group's session. This was intentional since the pilots participating in the actual flight test were expected to have approximately one to two months between the simulation training and the flight test. When brought back after one month, all developmental pilots needed retraining and simulator practice sessions to reach similar levels of proficiency as the previous session. These pilots did not have access to the CBT since it was in development at the time, and for some, it took nearly the full week to get back up to speed.

Pilots participating in the flight test were selected by their respective flight operations departments and included Honeywell flight test pilots, United flight test pilots, and

United line pilots. All of the pilots were current and qualified to fly the aircraft in the position(s) they flew during the flight test. Each had glass cockpit experience from at least two different manufacturers, were Required Navigation Performance (RNP) qualified, and had a minimum of 50 h of flight experience for the year prior to selection. The pilots ranged in age from 42 to 69 with an average age of 53, and had a diverse background in terms of hours, qualifications, and experience with flight tests. The pilots had each been flying from 20 to 49 years with total flight time accruals from 4,500 to 13,000 h. Nine pilots were selected and trained, and eight of them flew in the flight test itself. Boeing provided two FTDs who were also a part of the group training sessions. Both were familiar with the airspace used during the flight test, and one was a former air traffic control manager for the test area.

The pilots were specifically required to learn how to operate the prototype FIM software and operational techniques of the aircraft to conduct IM operations. Both pilots and flight test directors needed to learn how to coordinate the setup of flight vehicles prior to initiating a test run.

The procedure used by the pilots and FTD to set up the beginning of each scenario was as follows:

1. Using the aircraft's Flight Management Computer (FMC) estimated time of arrival function, each flight crew gave the FTD their respective time to a waypoint specified for that scenario.
2. The FTD then assigned specific scheduled time of arrivals (STAs) to each aircraft separated by three minutes (e.g., 0901, 0904, 0907 Coordinated Universal Time).
3. Each crew then managed their speed and ground track to achieve the specified STA prior to initiating the IM operation.
4. Once the IM operation was initiated, the spacing interval calculated by the prototype FIM avionics was displayed on the electronic flight bag (EFB), which the flight crew then communicated to the FTD.
5. The FTD assigned a new spacing goal based on the spacing interval previously given by the flight crew plus the spacing error defined in the test matrix for that scenario.
6. The flight crew reentered the FIM information with the new assigned spacing goal, then flew the operation by setting the FIM commanded speed in the mode control panel speed window.

The procedure described herein is particular to the flight test in order to achieve specific test criterion. In future operations with the ATD-1 concept fully deployed, ATC will issue a spacing goal and the pilot might not have knowledge of the error. The pilot will simply follow speed commands output by the algorithm to the conclusion of the IM operation. A breakdown by training modality is presented in the following sections.

3.1 Computer-Based Training

The CBT was developed using Adobe Captivate 9 software. Many airlines provide electronic learning to pilots frequently on travel via their electronic devices (typically an iPad) to allow anywhere/anytime training. The pilot gains knowledge via reading, video, and quizzes outside of the classroom, and alleviates some of the scheduling and financial burden for the airline by reducing overall time needed with an instructor at the training center. It has been demonstrated that prior training on a PC-based flight simulation package, regardless of the method to manipulate the flight controls, resulted in better overall performance than an untrained operator [7]. Dennis and Harris go on to describe, "…the best performance was observed in the group of participants that had prior simulation training using a representative set of flight controls to interact with…"

The NASA LaRC CBT was designed to provide a walk-through of the prototype FIM avionics, and allow the user to learn the layout of the system. The difference from most contemporary software is that NASA provided a manipulatable product to enhance ab initio flight training rather than static displays. This part-task CBT was the pilots' initial training on the FIM prototype system and took approximately 80 min to complete. The CBT was later supplemented with classroom academic instruction and training in high-fidelity simulators.

The CBT allowed the users to conduct training at their convenience, could be repeated as often as desired, and contained no pass/fail pre-qualification, enabling the user to make mistakes without fear of negative repercussions. Guided instruction was provided before most button presses in beginning modules. Later modules followed similar button pathways without instruction, forcing the learner to actively develop the cognitive template for the required task, and only provided guided instruction when new information was encountered.

The CBT was as close to the expected FIM prototype as possible (see Fig. 1 compared to [8]). Sized to the Electronic Flight Bag (EFB), the product looked dimensionally similar when viewed on an iPad and operated much like the FIM prototype to be used for the flight

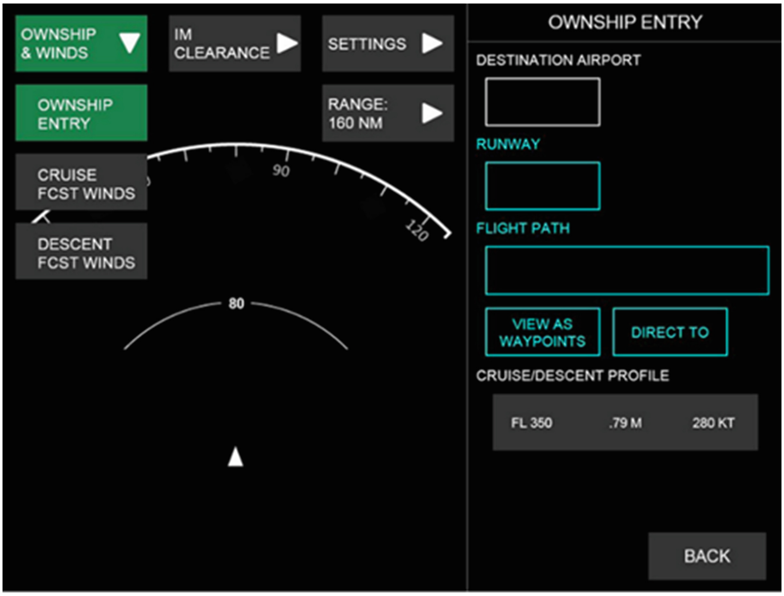

Fig. 1. CBT entry page example

test, therefore creating a realistic product that moved at the learning pace of the trainee. Training on a similar device allowed the pilots to practice task requirements.

Supplemental materials appended to the CBT included charts describing IM published procedures and a pilot guide which describes IM clearance types with associated graphics of each operation using a Standard Terminal Arrival Route (STAR), legends for all FIM displays, and descriptions of functionality for every button in the EFB.

The CBT chapters included: (1) CBT Info – How to operate the CBT, (2) Introduction – General overview of IM and primary aircraft components, (3) Ownship Entry – How to input Ownship information into the EFB, (4) Clearances – How to input Target information into the EFB by clearance type, and (5) Operation – Air crew procedures and operational techniques once engaged in IM.

The CBT discussed the flight test airspace, special STARs for the flight test, specific definition and description of four IM clearance types, a walkthrough of the FIM prototype Human-Machine Interface (HMI), and the flight crew procedures.

Pilots participating in the development phase did not have access to the CBT as the pilots participating in the flight test did. As a result, it was clear to the researchers that the pilots who had access to the CBT prior to arriving at NASA LaRC needed much less training time to learn EFB functionality due to the effectiveness of the CBT. Therefore, the CBT and all supporting materials remained available to the flight test participants during the interim period between training and actual flight with a brief one-hour refresher the day prior to the flight test.

3.2 Classroom Instruction

Classroom instruction further defined pilot roles and actions to accomplish the scenario setup and conduct the IM operation. The instruction at NASA LaRC was designed to provide graduated daily training to coincide with the simulator regimen. One and a half hours on the first day and one hour on the second day was dedicated to training. Focus was on Interval Management clearance types, walk-through review of EFB functionality, flight crew procedures, flight test card formats, and methods of managing the aircraft's energy to conform to the vertical path and FIM speed commands. The third and fourth day focused on crew and FTD integration, to include the FTD giving the morning briefing for the scenarios to be simulation flown that day, and answering questions from the pilots. Attendees included one FTD, one B737 flight crew, one B757 flight crew, instructor, and researchers associated with the learning task for the day. All remaining time during the four-day training session was spent in simulator training (described below). Each training day concluded with debriefing sessions to clarify irregularities and solidify lessons learned.

Interactive classroom instruction was employed to permit defining the flight crew procedures and information on the test cards. Classroom instruction reiterated training from the CBT. Immediately prior to the flight test, and approximately six weeks after training at NASA LaRC, two one-hour classroom sessions of training and review were given to the pilots. This consisted of a short walk-through of the prototype FIM avionics, aircraft operations while performing IM, and a question and answer period.

3.3 Simulator Training

The NASA LaRC B757 and B737 simulators were the primary locations for practicing EFB manipulation similar to the prototype and understanding user interactions between the prototype and IM operations. Simulator training occurred over four days to develop operational experience (including data entry on a labor intensive prototype), confidence, and scan technique with the added FIM displays. Following the classroom instruction on the first day, the flight crews initially went to their respective simulator for familiarization and part-task training of the IM procedure. Afterward, the two simulators and FTD desktop station were connected together to simulate as realistically as possible the scenarios to be flown during the flight test, with a pre-recorded Target serving as the lead aircraft in all cases. During the flight test itself, the flight test director was expected to operate from within one of the test aircraft using voice communications to disseminate information to the pilots of all three aircraft. Therefore, during training at NASA LaRC, the FTD was staged separately at a desktop simulator station to emulate the FTD flight station during the real-world test. The distributed simulation provided audio connectivity and Cockpit Display of Traffic Information between all simulators and also included simulated traffic similar to typical traffic in the planned flight test location.

In stand-alone mode, the training in the simulators provided the pilots the opportunity to familiarize themselves with data entry into the FIM prototype and practice the pilot procedures to conduct a IM operation. The integrated simulations with both flight crews and the FTD provided the opportunity for all participants to practice the procedures to conduct multiple IM operations during a single flight and understand the pacing for data entry. Trainers allowed both pilots and the FTD to make mistakes, and gave positive encouragement for successful planning and execution. Instructors narrated a run summary prior to each start, emphasizing specific pitfalls to recognize and avoid, including an explanation of the FIM algorithm operation. The algorithm is a closed-loop system whereby errors or delays in implementing the commanded FIM speed simply result in issuance of a new speed command when the original command is not followed. Once this was known, the pilot fixated less on the speed command window and focused on the operation in general; in effect, reducing pilot workload and overall stress when attempting to adhere to the assigned task.

Exploratory learning was guided during initial simulator training, and then a ‘hands off’ approach was used during later lessons while instructors added realism to the simulation by providing radio inputs as ATC and other traffic. Quick reference guides were provided to manage programming the EFB, if needed. Data cards were also developed detailing key information specific to each run. The flight test consisted of 38 test conditions, where each aircraft had a separate start condition based on the run, resulting in 114 data cards (38 conditions $\times$ 3 aircraft). For training, a smaller set of runs was selected that represented the majority of conditions expected for the flight test. The scenario setup design flowed from simple clearance types to complex, which progressively increased pilot workload.

The pilots and FTD also received operational procedure training to accurately pre-position aircraft on the appropriate STAR for that scenario to within three minutes of goal times prior to executing an experimental run. The FTD was specifically given extra opportunities for exploratory learning to develop the correct mental model of aircraft positions by testing various time intervals between aircraft and start locations to see what worked best. The FTD was able to develop correction strategies to manage cases where the initial spacing error was too far out of range. In some cases, towards the end of the training program, the NASA instructor left the training area during critical phases of decision-making and remotely observed the FTD and pilot interactions to ensure the scenarios were being executed as desired.

4 Effectiveness of Training Program

Critical components of the training regimen which led to the success of the flight test were pilot understanding of Interval Management, the development of flight test cards for the pilots, setting time goals to ensure correct aircraft positioning, and establishing constructive interactions between flight test crew members. After the conclusion of the flight test, six of eight test pilots completed a survey about the effectiveness of each learning method and any need for improvement. During the flight test, the Ownship used a spacing interval of either time or distance to determine separation from the Target aircraft. Pilot actions to conduct both operations were identical in either case. Numerical analysis of time-based operations is used below to provide an empirical example of learning transfer since these were the majority of flight test results. More detailed analysis of the flight test can be found in [9]. The success of the training is discussed next in terms of pilot feedback of the CBT, classroom training, knowledge transport in simulation training, and operational effectiveness during the actual flight test.

4.1 CBT

The majority of pilots indicated their needs were met by the CBT through repetitive physical programming and overview of IM clearance types. Following the flight test, pilots suggested additional modules desired for future CBTs should include contingencies to FIM abnormalities and an instructional video of data entry prior to the interactive portion. The authors believe a video showing entry for each IM clearance type would be beneficial to the learner. The CBT and flight simulator EFB were created during different development periods of the prototype FIM software, leading to slight differences in practice devices. Several responses stated the need for identical training products to prevent confusion during training. The pilots also reported that the CBT would have benefited from a clearer description of the FIM avionics prototype, in particular the displays and messages shown to the pilots. They also stated a defined correlation between the Target aircraft's behavior and its impact on the IM operation would be relevant to future FIM pilots.

4.2 Classroom Training

The majority of pilot responses to the training survey stated classroom time devoted to FIM should be minimal to none, indicating higher knowledge transport from the CBT and flight simulator training for the majority of pilots. The maximum classroom time desired by pilot respondents in future training was two hours. However, from the instructor's perspective, two pilots benefitted more readily from the classroom setting than the CBT due to highly interactive conversations. Classroom debriefs following simulator training were invaluable to pilot understanding.

4.3 Simulator Training

During flight simulator training, researchers observed seven of nine flight test pilot trainees with no Interval Management flight experience were able to adequately program the EFB and follow most speed commands by the end of the first day (<4 simulation hours). All were able to do so by the end of the second training day (<7 total simulation hours). When asked, "How many hours of simulator time do you think it took before you felt comfortable performing Interval Management following a Target aircraft?", the average response was four hours. Pilots suggested IM integration with line operation training would be preferred over stand-alone IM training to minimize simulation training time. One pilot commented simulator training time and value would be optimized if multiple, short scenarios focused on EFB programming, stopping once FIM guidance is initialized. Subsequent simulation training could concentrate on operational techniques while FIM is active. When asked, "What percentage of simulation time was spent learning how to program the EFB?", pilot perceptions ranged from 20% to 80% with an average of 58.75%. While the sample size is very small, this does indicate the FIM avionics prototype required a high mental workload as currently implemented. Some pilots believe an overall reduction of button presses for subsequent prototypes will reduce training time. Unless changed, a quick reference guide would be "extremely helpful" in the training environment. Respondents noted that simulation time could be minimized if FIM and RNP approach training were integrated, since both are expected NextGen products and could be accomplished using similar training tactics already in place.

4.4 Operational Effectiveness

The pilots were able to accomplish 157 flight test runs over 19 days [9, 10]. Though exceeding the desired goal of 124 runs, not all runs fit within the planned test matrix. Initial flights of the prototype software revealed critical anomalies allowing only a few runs per day. Correct coordination between the FTD and pilots ensured initial start times were relatively accurate, but some runs were filtered from the data set due to the anomalies. As the underlying issues were corrected and pilot and FTD experience increased, the number of planned runs increased to seven per day. A total of 129 time based runs were recorded with FIM spacing goals ranging from 124 to 300 s and a mean spacing interval of 178 s. Of the 118 time-based operations deemed feasible for evaluation at the final approach fix (FAF), the mean error from spacing goal at the FAF (i.e., completion point) was approximately two seconds [9]. This equates to within 1% of the mean desired spacing interval, indicating the pilots were able to execute the procedures they learned during training to conduct the IM operation and achieve the desired spacing goal.

Of the 129 time-based operations, 106 required the pilot to enter an assigned spacing goal, while for the remaining 23 time-based operations the spacing goal was calculated by the IM avionics prototype to maintain the current spacing between aircraft. The desired range of correction was from 60 s early to 60 s late with increments of 0, 15, 20, 30, and 60 s in both directions (−60 to +60 s). Across all analyzed runs, the absolute value of the average difference between the initial spacing errors the pilots were trying to achieve and actually achieved was 28 s. The training and procedures described in Sect. 3 was one impact to this metric, however it was also potentially impacted by differences between aircraft flight management systems and the difference between the forecast winds and actual winds. Training strategies employed by the FTD to mitigate instances where aircraft positioned outside the desired range also influenced this metric.

As a measure of learning transfer, we can observe how trained versus untrained crews positioned aircraft prior to each run. The crews onboard two of the three flight test aircraft had undergone simulator training at NASA LaRC to practice the operational setup of aircraft prior to the start of a run. Of runs analyzed, 57 run setups involved both Ownship and Target crews which had trained, while the remaining 49 contained one crew without training. During the flight test, the crew of every aircraft acted independently using holds and speed inputs to meet the STA given by the FTD by the start of the run. Considering 60 s as the maximum deviation for initial spacing error, the setups with wholly trained crews achieved this criteria 95% of their attempts, while the setups with one untrained crew achieved this criterion in 73% of their attempts. Additional information was unavailable to conduct a more complete analysis, however, the fact that crews trained at Langley consistently positioned their aircraft closer to the conditions on the test card compared to the crews not trained at Langley is suggestive of the effectiveness of the training program. Over the course of 19 flight days, the deviation from the desired initial spacing error did not appreciably improve for either type, indicating improvement was not a function of training, but potentially due to the tools available to the flight test participants attempting to position the aircraft as ATC would in the NextGen environment.

During the time-based runs analyzed, the pilot responded to new commanded speeds an average of 10.6 times per run, which corresponded to 0.57 speed changes per minute of operation using the mode control panel to enter a speed command [11]. The pilot took an average of 8.51 s to input each new speed command with dispersion of 5.8 s. Based on previous research [12, 13] and researchers' observation during the training regimen and flight test, the authors speculate there was strong retention of knowledge from training. The flight crew typically programmed all variables to the EFB correctly, allowing active engagement of the FIM system, and responded to speed commands in a timely manner as trained, leading to a high degree of accuracy for the operation.

5 Future Training

In the future, IM operations may become the norm, therefore requiring less extensive training for understanding the use of the procedures. It would be expected that initial IM information from the FAA would be followed by training materials and CBT products developed by individual airlines and training vendors. Within the airline industry, CBT can maximize pilot availability, allow the airline to track student understanding and time spent on each subject area, and can register whether the learner has completed coursework. Using CBT, the pilot can preview the subject material ahead of instructor guided classroom learning. A fully functional version of the system interface can permit the user to gain operable experience through exploratory learning, and testing the interface. The classroom experience can be maximized by using that time to reiterate and interactively test working knowledge with an expert instructor, thereby developing user confidence and trust in the system. Regarding future FIM flight simulation training, pilot comments suggest introducing ATC communications across multiple controller handoffs to create additional realism for better transfer of knowledge. Pilots stated that understanding the algorithm behind FIM was not required for training, but specific procedures for Ownship programming and Target selection must be trained.

Based on the experience of the flight test, the close timeframe of all three activities, CBT, classroom training, and flight simulator training, resulted in a cohesive program that was satisfactory and relevant for all participants. After completion of such a program, pilot responses indicated access to a CBT should be a minimal requirement for the interim period between training and later flight use to refresh skills as needed. Continued access to learning materials following the program would help promote continuity of training.

6 Summary

Prior to conducting a flight test of a prototype FIM system for ATD-1, NASA realized pilots and FTD training prior to the first flight was critical due to the unique and complex nature of the software and the operations themselves. A learning regimen was devised that incorporated CBT, classroom instruction, and distributed live simulator training. All three phases were interactive and occurred over a short timeframe to allow learners to progress from rudimentary understanding of the concept and software, to manipulation and control of the aircraft, to setting up the scenarios and flying the IM operation. Key features found to be successful in assisting the pilots to correctly set up the scenarios and conduct the IM operation included repetitive physical programming to learn the system, CBT to minimize or make classroom time more constructive for the learner, integrated training with other team members, and progressive training of more realistic and complex simulation scenarios. The results of the ATD-1 flight test training regimen offer strong evidence that a fully functional CBT enabled the pilots and FTD to have effective exploratory learning prior to the classroom instruction and simulator training. The integrated simulator training allowed the pilots and FTD to practice conducting the IM operations in a live and interactive manner, which proved to be essential during the flight test itself to maximize the number of scenarios flown each day. The short duration between the three training methods, and the short duration between the conclusion of the training regimen and the beginning of the flight test, contributed significantly to the overall effectiveness of the ATD-1 training program.

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Enhanced Pilot Learning Interface

De Michael Kiss(✉)

College of Engineering and Computing, Department of Human Centered Design,
Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901, USA
dkiss2014@my.fit.edu

Abstract. This paper describes an informational navigation tool to augment airline pilot learning. The device is designed to decrease the amount of time required to navigate aircraft manuals when searching for aircraft operational information, including: (a) Aircraft systems and systems integration, (b) Aircraft performance, (c) Checklist usage and flows, (d) Alerts, and (e) Limitations. Current paper and digital methods are challenging to circumnavigate. As a result, pilots can lose efficiency in time and cognitive development using state of the art methods. To improve learning resources, I have developed the Enhanced Pilot Learning Interface, an Interactive Media for educational applications. Preliminary tests of current professional airline pilots have demonstrated an efficiency increase of 65.5% using the Enhanced Pilot Learning Interface when compared to state of the art methods.

Keywords: Advanced Interactive Media · Affordance · Aviation education Cognitive resources · Complex transport category aircraft · Decision making Human System Integration · Interactive manual · Meaningful learning Mental model attributes · Airline pilot training situational awareness

1 Introduction

During the last several decades, transport category aircraft systems have become more complex as automation allocation has been granted increased authority in the flight station [1, 2]. The intentions were to reduce the number of required pilots, lessen pilot workload and enhance safety [2, 3]. During this human-system-integration (HSI) evolutionary maturation process, the role of the pilot has shifted from that of a manual operator to that of a manager of systems and automation [2].

While automation was intended to reduce pilot workload and enhance safety, there is a caveat [4]. Modern transport category aircraft systems and their interaction require a deep knowledge and understanding of their operations during many different environmental flight conditions and in-flight abnormal or emergency scenarios [5].

Currently, no commercial aircraft, however advanced, can be safe without a competent crew. This requires significant education, experience, and training for a pilot to develop the necessary skills to safely interface with the modern complex transport category aircraft [3–7]. Therefore, a great amount of training hours must take place before any pilot can participate as a flight crewmember. Additionally, crews must understand

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the systems and how those systems interact during normal, abnormal, and/or emergency scenarios [3, 8].

Two types of training exist within the airline domain:

- Systems Training (Declarative Knowledge) and includes:
  - Systems knowledge
  - Systems integration knowledge (how the systems interact)
- Procedural Training (Procedural Knowledge) and includes:
  - Normal flight operations
  - Abnormal flight operations
  - Emergency flight operations

During simulator training, pilots repeatedly practice scenarios to develop and enhance their expert skills operating a complex transport category aircraft. This training helps influence positive behavior during emergencies as such practice helps pilots to act in a reflexive, natural, and instinctual manner [6, 9]. Cognitive resources acquired during simulator training become automatic over time during procedural practicing and this is known as automaticity [5].

For a pilot candidate to transition to the simulator and begin procedural training, he or she must complete their systems training so they possess the declarative knowledge required to succeed. Often, as a simulator instructor, I have found that candidates were not procedurally prepared because they had lost time trying to find system information during the systems study. Therefore, there was less time available to study procedures and they lacked the necessary procedural knowledge.

While major advances have been made in simulation technologies, the improvement in knowledge transference methods appears not to have progressed significantly. Hence, the current materials used by airline pilots and pilot educators to acquire system knowledge may be outdated. The question is, can current technologies be used to enhance pilots' training, and, if so, how?

1.1 Complexity of Navigating Current Information Transference Methods

In today's airline industry, current paper and digital knowledge transference methodologies are complex and arduous to navigate. They can make it difficult for pilots to find system information, needlessly increasing the time required to accomplish individual tasks when pilots seek to resolve specific "what-if" questions they ask themselves after anticipating problem scenarios during their systems training.

Additionally, because many pilot candidates report to the simulator with less then the required knowledge needed to begin procedural training, time is lost in the simulator. This reduces the time available to meet the minimum requirements mandated by the FAA during simulator training, increasing costs for the airline.

Therefore, the primary research question that guided this research was, "What if we can reduce the complexity of navigating the aircraft manual? Could reducing the navigational complexity reduce the time it takes a student pilot to find system information? If so, could the extra time gained be available for the student to learn their procedures?"

Note: The research hypothesis is the reduction of time saved to find system information, and could this result in a higher quality learning experience. What the pilot candidate does with that time specifically is beyond the scope of this paper. Further, there is no attempt to reduce the required training hours mandated by the FAA. On the contrary as there is evidence for increased learning. The goal of the research is to adapt the training and allocate the conserved resources for augmented learning.

1.2 Process of Current Information Transference Methods

When using existing methods to find information in an aircraft manual, students must:

- Identify the correct scenario (abnormal/emergency)
- Pick up the manual
- Identify the chapter corresponding with the concerned system
- Find the proper panel
- Find the wanted item in the list
- Turn to that page
- Scan the page to find the desired information

Therefore, using current technologies, pilots are information sorters rather than information selectors [10]. They must sort through a milieu of data to find the desired information within the specific context of the "what if" scenario. What is more desirable then sorting for information? Selecting the desired information! Thus, what if individuals could become information selectors rather than information sorters, could this reduce the navigational complexity in searching for information. I.e., if a person could choose the information they want as opposed to tabbing or flipping through pages of paper-based manuals or scrolling through digital-based manuals, would they conserve time, and could that savings be reallocated for more learning?

Additionally, it is my experience as a student, pilot, and instructor, that when an individual is navigating numerous pages to find information, motivation is decreased, and cognitive fatigue is increased. This can lead to frustration. In other words, it takes mental resources to locate the information [11].

Therefore, finding information under current state of the art methods is less then desirable. What if finding information became a more enjoyable experience? Consequently, the goals in designing a navigational platform to aid pilots' learning were defined to address these questions.

2 Enhanced Pilot Learning Interface (EPLI)

2.1 The Concept

Currently, trainees must spend more time and dedicate themselves to learn the deep declarative knowledge of an aircraft's systems, systems integration, aircraft limitations, procedures, and warnings [3]. This is needed to transition to simulator training. Without that knowledge, trainees would not be able to perform adequately during the simulator training. I have hypothesized, "What if we could reduce the time it takes trainees to find system information, and, if so, could the time saved be reallocated to the procedural side of training so that students would be better prepared for procedural training?

With today's technologies, and using Human Centered Design (HCD) philosophies, we can enhance the current approaches [2]. Different options were explored and the following are possible methods that can be applied to enhance current state of the art methods:

- Reduce the complexity of navigating manuals
- Apply natural affordances for ease of informational navigation
- Use visualization
- Integrate accelerators (icons vs. tabs or indexing)
- Link contextual information to inputs (I.e., icons on a tablet face)
- Add the right amount of granularity (the amount of information inserted into graphical display, based on input from experienced pilots) into current technologies.
- Provide efficient navigation for
  - User-System Interaction
  - User-Systems Integration Interaction
  - User-Procedural Interaction
  - User Checklist and Flow Interaction
  - Alerts Interaction

These and other methods could be utilized to develop a new platform that could enhance navigating an aircraft manual; the static paper and/or digital documents could be transferred into a structure called Integrated Navigational Documents (INDs)—developed in scope of this research. INDs contextually link the visual Icons of an Advanced Interactive Media (AIM)—in this case, the Microsoft Surface Pro tablet—using Interaction Descriptors (IDs) and Interface Objects (IOs).

When combined, the hardware and software interaction platform, INDs, IDs, and IOs fashion a new learning device, the Enhanced Pilot Learning Interface (EPLI). The collective organization transforms static paper-based information into actively changing content.

The very first concept trials demonstrated surprising emergent properties. The EPLI influenced user attitudes as they enjoyed working with the device and expressed the desire to spend more time interacting with the EPLI. Therefore, an emotive factor exists that appears to enhance motivation for interacting with the device.

2.2 Designing EPLI

In conceptualizing, designing, and producing EPLI, my experience as an airline pilot (31 years as a U.S. major airline pilot), in combination with my simulator instructor experience, understanding the learning and training processes, and applying my Human Centered Design education, led to discovery of the users' cognitive functions. With my expertise and HCD training through a research assistantship, I could consider, conceive, and integrate a task analysis [11] for the initial development of EPLI (See Fig. 1 on the following page). The task analysis inspired the following concepts and technical and system operations components that would be needed for EPLI's introductory design requirements:

- A proper input system (Tactile touchscreen)
- Symbol representation (Familiar system icons) that incorporated
- Associated language (Aircraft manual) embedded within
- Contextual links (mind mapping) to
- Inspire the desired system actions and
- Reduce the complexity of current navigation methods

The goal was to accelerate user-system interaction and enhance the Human System Integration (HSI) experience [12], reducing the amount of time it takes to find information. When the interaction style is easy, access to meaningful information is facilitated [13].

Integrated Navigational Documents (INDs) were developed using Interactive Objects (IOs) and symbolic icons as Interactive Descriptors (IDs) in combination with Computer Integrated Documents. These INDs contextually link the different domains of study in an advanced jet transport category aircraft manual. In other words, INDs permit static documents to dynamically change accordingly when evolutionary dynamic changes occur during cognitive scenarios of different conditions engendered by "what if" questions that pilots contemplate during systems integration study.

In this way, pilots develop instinctual safety convictions by asking these intellectual "what if" queries throughout diverse phases of flight, with different scenarios they conceive. This is to afford stability resolution when unwanted and/or unforeseen events occur [14]. Conversely, INDs make available an animatedly context sensitive plan that provides the user with quick answers to contextual "what-if" scenarios as the user sees fit. This also provides the user with an enjoyable sense of interaction [8]. Most importantly, they feel in control of their study time, enhancing their attitude and motivation [12].

2.3 Meaningful Learning

Meaningful learning inspires an individual to develop a combined context of concepts and propositions that are hierarchically organized into a prearranged domain of knowledge [15]. Skilled expert knowledge develops over time by means of a process of continuous meaningful learning through education, practice, experiences and real-world HSI operations.

This process helps people use supplementary knowledge to problem solve and facilitate future meaningful learning [15]. Compared to rote memory practices, meaningful learning establishes knowledge schemas within long-term memory. Consequently, knowledge is generally retained longer, further enhancing future creative thinking for novel problem solving [14]. In association, pilot meaningful learning could be augmented by contextually linking operational documentation with interactions of different scenarios. Therefore, we need to identify and understand concepts and propositions integrated into human cognitive structures of sensory perception, mental processing, decision making, actions and feedback mechanisms [16]. This understanding provided further bases for the design rationale.

2.4 EPLI Prototype

Once the concept of EPLI was defined, there was a need to build a prototype to test the validity of the above described theory and gather feedback from users (See Fig. 1).

Fig. 1. Concept image of EPLI displayed on a tablet

First, a wireframe prototype was developed using Microsoft PowerPoint. Slides incorporating images and text were developed into text boxes which were then contextually linked between different slides, simulating IOs and IDs. Icons were then defined, linking the slides to other pages, thus creating an easy way to navigate through the pages (See Fig. 2 on the next page). The wireframe was then installed into a Microsoft Surface 3 Tablet and tested against existing information navigation methodologies using four expert airline pilots to see if the device would indeed reduce the time it took to navigate documents.

From the main page (See Fig. 2 on the following page), users could access six categories:

- Systems
- Alerts
- Checklists
- Flows
- Procedures
- Flight Management

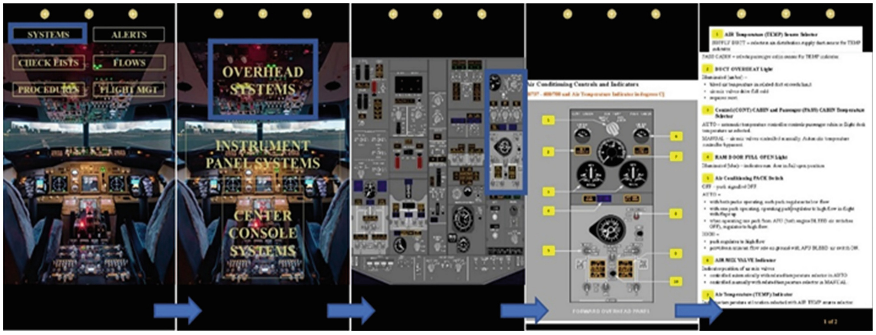

Fig. 2. Example of navigating aircraft systems using EPLI

The SYSTEMS section provides information about the different systems of the aircraft, by accessing narratives and schematics. The ALERTS section is for discovering the meaning of a warning light or indicator. The CHECKLIST portion navigates the user to a list of all the normal, abnormal, and emergency checklists. Finally, the FLOW segment directs the trainee to the associated flows (visual representations of the successive items appearing in the checklists). The PROCEDURES and AUTOMATION sections lead the student to those areas of study.

2.5 Preliminary Testing

Preliminary testing of the wire frame prototype has demonstrated the initial reduction of time spent finding information using EPLI. Four experienced airline captains were timed when asked to find information related to two different lights, using the static paper, the digital, and the EPLI methodologies. The results show an average 65.5% diminution of the time needed to access information using EPLI when compared to the paper and digital methods (see Table 1).

2.6 Findings

The preliminary test sample indicates that the resource time, can be better utilized with EPLI and tends to show the validity of the concept. Because experienced airline pilots were tested, we can infer there is a correlation from the results of the sample (n) of 4 FAA Part 121 pilots that can be applied to the population.

We discovered that EPLI does allow pilots to find the information they need to answer their what-if scenarios quickly and efficiently. Consequently, they become information selectors and reduced the time required to find answers to the questions. Thus, it can be concluded that time and cognition resources can be conserved and applied to other areas of learning. This was due to enhanced efficiencies by reducing the information navigation complexity. These potential affordances are described in Fig. 3.

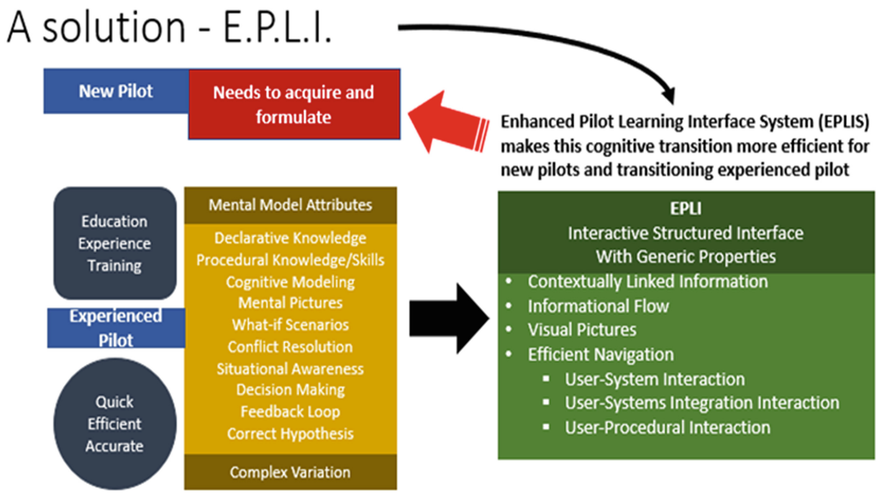

Fig. 3. Diagram of potential EPLI Affordances for new and experienced pilots and a transfer of experienced pilot mental model

Additionally, all four test subjects expressed great interest in using EPLI and stated they wished they had a similar device to learn new aircraft. Moreover, the subjects further stated they greatly enjoyed using the device and felt an emotive connection that increased their motivation and desire to learn more. Therefore, I will incorporate a questioner for the next testing phase to collect this important data.

Table 1. Initial EPLI testing results with four expert airline pilots

Expert	Qual/Hrs	DCT OVHT	DCT OVHT	DCT OVHT	WNG OVHT	WNG OVHT	WNG OVHT
		PAPER	DIGIT	EPLI	PAPER	DIGIT	EPLI
CPT. D	20K	22 Secs	30 Secs	7 Secs	17 Secs	26 Secs	5 Secs
CPT. J	18K	16 Secs	26 Secs	6 Secs	12 Secs	13 Secs	5 Secs
CPT. K	17K	17 Secs	18 Secs	5 Secs	9 Secs	17 Secs	6 Secs
CPT. S	18K	11 Secs	18 Secs	5 Secs	10 Secs	20 Secs	7 Secs
AVERAGE		16.5 Secs	23 Secs	5.75 Secs	12 Secs	19 Secs	5.75 Secs
EPLI VS. PAPER		10.75 Secs 65%			6.25 Secs 52%		
EPLI VS. DIGITAL		17.25 Secs 75%			13.25 Secs 70%		
Overall Enhancement	**65.5%**	65+75+ 52+70	= 262/4	= 65.5%			

3 Improving EPLI

3.1 A New Tablet

During the testing and working with the professional pilots, we found that EPLI needed several other design requirements to be added. Therefore, an entire software team of FIT undergraduate students was selected from the College of Engineering and Computing. We are currently updating the software, graphics, contextual linking, and icons this semester. The goal is to have the new working prototype available for testing during the summer of 2018 and report the results of the testing at the end of the summer.

3.2 Augmented Reality

After testing and validating the functionality of the iterated EPLI system, the next step will be to transfer the capabilities of the tablet to augmented reality utilizing a wearable system. This will allow us to test pilots using EPLI in a Flight Training Device (FTD) (simulator). The goal is to afford pilots, sitting at a paper-based mockup (with no other physical references), the ability to make the instrument panels come to life using glasses, a computer, and cardboard. The goal is to have the augmented reality prototype available for testing during the fall of 2018 and report the results of the testing at the end of that semester.

4 Conclusion

The main objective of this project was to determine if it is possible, using recent technologies, to improve the current knowledge transference methodologies. I have shown that by contextually linking visual icons to system information via Interactive Objects and Interactive Descriptors in combination with Computer Integrated Documents, it is possible to simplify the complexity of navigating aircraft information in a manual and, therefore, the resource of time can be conserved. Testing a basic prototype using a wireframe with professional airline pilots has proven the concept.

These evidences have warranted further development of improved software to be allocated for a new prototype which is in production at the time of this writing. Much has been done to ensure that the prototype will meet the philosophy of Human Centered Design, and the promising results obtained by the first prototype seem to augur a bright future for the concept.

Once complete, the prototype will be tested using multiple scenarios, with different populations (newly hired pilots, transitioning pilots, and highly experienced captains), to confirm or invalidate the hypothesis behind the EPLI artefact. If confirmed, it is possible the concept could be extended; for example, by creating a similar system for augmented reality and the possibility of use as an on-board context sensitive device for addressing abnormal and emergency situations. Further testing of that prototype with a large sample of FAA Part 121 airline pilots should indicate the validity of the hypothesis or not.

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Refocus Attention Towards Observing in Design Foundation Education

Magnus Feil(✉) and Milagros Zingoni

The Design School Herberger Institute for Design and the Arts, Arizona State University, Tempe, AZ, USA
{mfeil,mzingoni}@asu.edu

Abstract. The ability to create sophisticated artifacts to improve life has been a hallmark of the human species. Over the years we've reached a point where nature has come to play a minor role in our daily lives. This affects almost every aspect of our existence: transport, housing, food production, communication, entertainment, etc. Such technological advances have brought efficiency, convenience and safety. Modern life would be unthinkable without the technological amenities and systems available to us. As a means of survival in a potentially hostile world, we have changed from active observers and participants within the environment into merely passive actors within the boundaries of a manmade reality whose comforts we have taken for granted. With the development of modern forms of communication beginning with the radio and television and recently the Internet and virtual reality, we have become further distanced from the natural world. It is now possible to live completely detached from nature. For everything natural, a substitute has been created. Even the intangible human imagination has been desensitized and "dis-trained" to see the world in a particular way that is now mediated by technology. Furthermore, the pacing of modern life leaves little room for rest, contemplation and reflection. This poses a great risk for aspiring designers who are tasked to envision a better world. It has become easy to draw upon information from far-flung places via the Internet, yet we neglect what lies in our immediate surroundings. To address this, John R. Stilgoe astutely calls for "regaining history and awareness in everyday places" in his manifesto "Outside Lies Magic" [1]. In the context of Design Foundation Education, it is essential to stimulate the skills of observation and discovery as a prerequisite for problem solving. The environment around us offers a surprising amount of solutions which can be unlocked when we access all of our senses. For design educators, it is critical to remind students that solutions can be right in front of them when they are willing to go outside. This case study intends to refocus attention towards observing what is already there in close physical proximity. With all the discoveries to be made outside, impressions can lead to a more thorough understanding of our environment and ultimately stimulate better solutions.

Keywords: Design education · Design foundations · Observation · Discovery Environment · Affordances · Storytelling

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1 Introduction

In his book "*The ecological approach to visual perception"* J. Gibson sees natural vision as "depending on the eyes in the head on a body supported by the ground [...]. When no constraints are put on the visual system, we look around, walk up to something interesting and move around it so as to see around it from all sides, and go from one vista to another" [2]. This stands in contrast to Gibson's definition of Ambient and Ambulatory Visions in which observers' head-movement (ambient), or the ability to move around to perceive (ambulatory), are artificially constrained in lab experiments resulting in perception akin to a "single frozen field of view [that] provides only impoverished information of the world" [2].

Students often succumb to the temptation of exercising/practicing secondary design research as a quest to search for imagery of often loosely related artifacts on the internet. Images displayed on two-dimensional screens hereby stand in stark contrast to Gibson's concept of natural vision. Yet, services like Google or Pinterest offer a nearly unlimited stream of visually appealing material to serve as an inspirational umbrella encompassing the students' task of "problem solving". Instead of solving problems, the search for images as inspiration is likely to create a set of new problems for the learner. Not only does an image rarely convey the rationale and/or intent of the original designer, but collecting found imagery of designed artifacts often results in a misconception that "all the good ideas have already been taken". The risks of this acquired behavior and resulting mindset are twofold: No deeper understanding of a given problem is reached, consequently impeding the student's ability to climb up Maria Popova's "Ladder of Understanding" towards (domain) knowledge and wisdom [3], resulting in frustration and stagnation of the design progress. Secondly, the mere unearthing of already existing concepts, paired with a lack of original ideas, often leads to students taking inspiration from individual visual elements of their searches, and simply combining them into something they consider new. Although, compared to other academic disciplines, the definition of plagiarism versus inspiration in the fields of art, fashion, architecture, and design sometimes leaves more leeway for finding "inspirations" from the past and present. I find such behavior highly unethical nevertheless, and stop students in their tracks whenever I see it.

In general terms, we tend to go to our smartphones and/or the internet as our default go-tos for information. We no longer seem to be able to see other options such as original discoveries derived from direct observation. Instead, we accept mediated information from the outside, regardless of its validity or backgrounds. In the context of design education, it has become easier than ever for students to find inspiration and examples for any given problem. This is not necessarily bad. It does, however, tend to foster a dependence on such sources. Ideally, these inspirations should lead to a development of new and original ideas. The internet is at best, a provider of raw data and secondary research. While this is valuable, it tends to delude designers into mistaking visual information for facts. The act of direct observation and discovery is an attempt to foster the student's agency in the design process. "All genuine learning is active, not passive. It is a process of discovery in which the student is the main agent, not the teacher" [4].

2 Where We've Come from

In "primitive" societies, that is, those which live much closer to and are more dependent on the vagaries of nature than the one we presently live in, a respect, awareness and attunement to nature is essential for survival. This primacy of nature in their lives necessitates their being more active participants in the natural world. They are more producers and creators. "Modern" societies have seen a shift that has occurred over millennia toward more and more specialization that has separated people from their producer-creator origins to that of primarily consumer. With that our attention has shifted to a vastly expanding artificial environment, both physically and virtually. Instead of being producers we have become consumers by default. An important task that lies ahead for design education is to reconnect and rebalance our imaginations with the creative possibilities and potential that lies in the world outside. A better awareness of our surrounding environment has the potential to provide us with a rich resource for inspiration for problems which may defy straight-line or logical solutions.

> *"The whole concentration of wild and artificial things, the natural ecosystem as modified by people over centuries, the built environment layered over layers, the eerie mix of sounds and smells and glimpses neither natural nor crafted – all of it is free for the taking, for the taking in. […] Outside lies utterly ordinary space open to any casual explorer willing to find the extraordinary. Outside lies unprogrammed awareness that at times becomes directed serendipity. Outside lies magic."*
> *– John R. Stilgoe* [1]

3 Where We Want to Go; *Dis-training to Re-training; the Re-sensitizing of the Imagination*

The observational skills and imagination once essential to human survival in ambiguous/hostile environments, has not fallen by the wayside. Our senses, curiosity, and playfulness are still an inherent factor in how we interact as humans with both each other and the world. In Amos Rapoport's book *The Meaning of the built Environment*, the author highlights the notion of "environmental meaning as a form of non-verbal communication and those behaviors related to the interaction and communication among people". Anthropologists share the position "that in all cultures, material objects and artifacts are used to organize social relations through forms of nonverbal communication; that the information encoded in artifacts is used for social marking and for the consequent organization of communication among people" [5].

For design educators, it is essential to redirect these qualities towards increased awareness and observation of the environment around us. Following Stilgoe, we are surrounded by a multi-layered mix of man-made and natural realities and interactions, open to absorption by open-minded observers [1]. Rapoport sees four distinct categorizations of the environment, which he calls elements: 1. *Communication* in reference to verbal or nonverbal communication; 2. The element *meaning* representing "nonverbal communications from the environment to people"; 3. *Space,* and the organization thereof, "for different purposes and according to different rules"; and 4. *Time* as the element in recognition that the environment is not only a living space but equally temporal, with organization of time "reflecting and influencing behavior in time" [5].

In design, the concept of "affordances" is difficult to comprehend and implement for many students and professionals. According to perceptual psychologist J.J. Gibson, affordances refer to "the actionable properties between the world and an actor (a person or animal)" [2]. Donald Norman states that "affordances reflect the possible relations among actors and objects: they are properties of the world" [6]. The concept of affordances is difficult to understand without analyzing it through experience. There is a myriad of misconceptions as to what affordances actually are or represent. Therefore, it is essential for design educators to approach the concept through observation in the outside world, and subsequently to discuss and analyze recorded discoveries for further clarification.

For educators teaching design foundation exercises, it is essential to reinforce this concept for learners by having them identify affordances in the environment as underlying principles for interactions.

With the realization that some things are invisible, designers are increasingly asked to design the often intangible (such as the internet of things), or complex interactions at the intersection between people, technology, and the world. Only a deep understanding of such relationships allows designers to gain expertise on the subject matter, which is contextual and "depends on more than just cumulative experience" [7].

An important task of the design educator is thus to make students aware of the many intersections possible by exploration interactions outside the lab/classroom. Advancing students' repertoire beyond the merely visually and/or verbal, multiplies possibilities for advancing design outcomes, and ultimately the quality of solutions. It enables both expertise and increases the richness of the story which design can tell.

The observation of the mundane leads to the identification of patterns of behaviors, objects, and visual languages and the seeing of the intersection of human action, technology and the world and designs. Awareness of such relationships offers the possibility of better understanding, and by extension helps in designing better methods of communicating and facilitating interactions. The design of affordances is one example of deliberate expression by translating observed behavioral patterns into embedded form and function.

4 Training of Observation, Discovery, and Understanding as Prerequisites for Becoming an Expert

In the process of discovery, observers are encouraged to see such complex relationships among actors, objects and the environment. Acquiring a deep understanding of the environment as prerequisite for expertise is essential for learners and professionals alike to envision better solutions for the observed.

4.1 Class Exercise 1

Objective: This simple classroom exercise aims to test the students' observation and recollection skills.

Embedded within the slides of a lecture on the German industrial designer Dieter Rams, two images of Braun radios were highlighted and discussed during the presentation. Unbeknownst to the cohort of undergraduate students, my special attention to specific images was aimed to sharpen their focus on the details contained within. At the end of the lecture, the students' observation skills were challenged by my request to apply their recollection skills by assembling the previously seen images out of individual elements. Prints containing the separated parts of the designs were hereby distributed, and students were tasked to cut out the pieces and join them together to match the original designs as closely as possible. Students used glue sticks to adhere their pieced-together recollections into a collage and share their results with the cohort (Fig. 1). Upon pinning the work to a wall, reference images were distributed to allow a direct comparison between the original and the students' recollections. The resulting collages ranged from highly accurate to rather humorous interpretations. Interestingly, a post-mortem discussion with the students brought an unexpected fact to light. The recreations of the original design were guided by both re-collection through observation and an understanding of the logic where the individual elements were supposed to be.

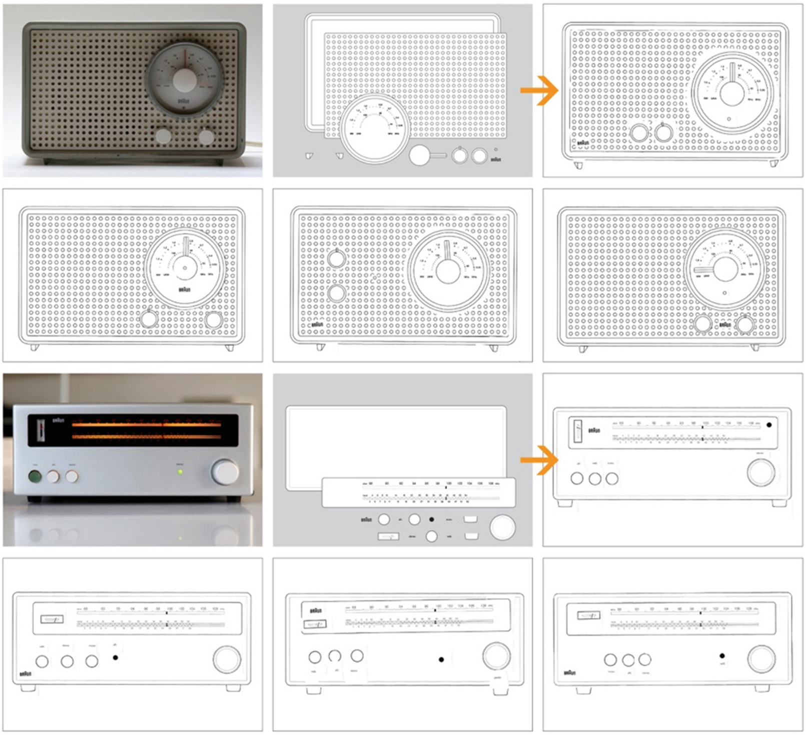

Fig. 1. Student exercise; Collages made from recollection (Feil, Student work, 2018)

4.2 Class Exercise 2

Objectives: Gaining a deeper understanding of "affordances" by observation and recording of artifacts in the wild, discussing purpose, analyzing function within the world of the objects found in the scavenger hunt, and the sharing of discoveries and ideas.

As homework assignment, students are sent out on a scavenger hunt to identify and rediscover artifacts normally not paid attention to. Students are requested to only use the camera function on their phones as means for observing, recording and sharing of the gathered impressions. The use of an optional geotagging app allows the spatial mapping of the students' discoveries. While it seems counterintuitive or illogical to use technology to observe unfiltered nature, the use of cameras allows students to 1. focus their senses, 2. capture what they see as important, and 3. share their observations with their peers in class. This exercise is less about photography than it is about honing one's visual sensitivity toward the world.

Upon completion of the scavenger hunt, student present their findings of their various discoveries within the environment to the class. Within two minute long intervals per slide, students are tasked to write down as many relations among actors and objects as possible. Upon completion of the slideshow, students are tasked to compare and discuss the attributes discovered.

Case Study of Telephone/Lamp Poles (Fig. 2). The underlying goals of this exercise is geared towards training observation skills, stimulate the students' senses, seeing of relationships, isolating discoveries from their surroundings, and to identify opportunities for

Fig. 2. Observational scavenger hunt; Examples of found lamp/telephone poles (Feil, Zingoni. 2015 - 18)

future design interventions. The examination of telephone and lamp poles as one example of discovery within the observed environment, yielded a vast array of observations:

Function: Aesthetics, utilitarian, load carrying, scaffolding for technical equipment, safety, "bulletin boards" - communication through posters, canvas for "guerilla art", political, advertising/commercial, support of traffic signage, message boards/messengers, multi-ethnic, iconic, invisible, eyesores, landmarks.
States: weathered, old, new, cold, hot; undisturbed, marked or modified, vandalized, damaged, abandoned, beloved, layered, burdened, heavy, light, busy, innovative, singular- or multi-purpose, independent or integrated in a system, variations within the larger system/environment.
Surface & Textures: Natural, treated wood, creosote, metal (zinc), paint, stain, smooth, rough, layered, staples, paper, stickers, decayed, rotten, covered/reclaimed by nature.
Sounds: wind, vibration, movement of cables, humming of high voltage, buzzing of lamps, birds.
Smells: Creosote, tar, paint, wood, metal, musty, decay, "dog urine".
Broader associations derived: Age of community, economic investment, vibrancy of community, indicator of affluence of the neighborhood, diversity and mindset of community, social status, political activity & power.

5 Outcomes, Conclusion, and the Road Ahead

The underlying premise is observing, recognizing complexity and consequently creating more meaningful design. Meaningful not only implies a match that complements and advances reality, but a path ahead towards better solutions at the intersection of people, technology, and the world.

Intermediate steps to take for both designers and design educators start with the recognition and embracement of complexity within our environment. We need to (re)discover better methods to stimulate observation and discovery at the core of our work. Both learning and design practice is a highly active process, and equally so is the need of communicating and sharing derived insights in meaningful ways. Mental/Intellectual stimulation of situational awareness through perception of affordances, appreciation of the richness of unexpected discoveries, awareness of environmental complexity and diversity, awareness of the temporal dimension embedded in our environment will lead to possible associations with students' home, location and identity. Subsequently, the physical creation of representations such as maps, charts/graphs, storyboards, collages, and/or multi-sensory displays form the foundation of storytelling to communicate both insights and complexity to the world. Lastly, an increased awareness of the environment will lead to strategic design solutions for both the environment and changes within. It fosters the establishment of a broader repertoire of design vocabulary, skills & understandings, and the potential broader cooperation with the community, government, and academia.

Design educators hence need to better embrace complexity in their teaching from early on. The meaning of "*designing from the inside-out*" has to be reexamined and turned on its head: The notion of "*inside*" are no longer the guts of the machine, instead it is our "*environment*" outside. The definition of "*designing from the outside-in*" is given a vastly new meaning all of a sudden! Magic found outside translates to the magic of creating better artifacts for our environment.

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Experimental Investigation of the Retention of Emergency Egress Competence Acquired in a Virtual Environment

Jennifer Smith[✉], Kyle Doody, and Brian Veitch

Faculty of Engineering and Applied Science,
Memorial University of Newfoundland, St. John's, NL, Canada
{jennifersmith, kdoody, bveitch}@mun.ca

Abstract. Retention of egress skills is critical during high-stress emergencies on offshore oil and gas platforms. This paper uses a virtual offshore platform to investigate the long-term retention of emergency egress competence. A two-phased empirical experiment was designed to first teach basic egress skills and subsequently assess skill retention. The first phase of the experiment used a simulation based mastery learning (SBML) pedagogical approach to teach 36 naïve subjects the necessary spatial and procedural skills to evacuate safely from an offshore platform. In the second phase of the experiment, the same participants were tested after 6 to 9 months on their ability to respond to a series of egress test scenarios. These results indicated that emergency egress skills are susceptible to skill decay. Recommendations to improve the retention of offshore egress skills are discussed.

Keywords: Offshore emergency egress · Simulation-based mastery learning Virtual training · Training retention

1 Introduction

Offshore emergency egress is a safety-critical skill that is an essential part of emergency preparedness. Emergency preparedness skills are typically acquired through conventional safety induction training. These skills are infrequently put into action because emergency situations are rare. Weekly muster drills are subsequently practiced onboard to maintain competence. Routine muster drills provide opportunities for crew members to practice their egress skills while working offshore. However, muster drills are limited in the practice they can offer because drills do no replicate the high-stress, dynamic, and hazardous conditions of emergency situations.

Current offshore safety induction training typically uses a fixed instructional time to provide offshore familiarization and safety training. However, fixed instructional time cannot address individual learning differences and can result in varied performance outcomes (i.e. fixed training hours can result in undertraining slower learners and over training quicker learners). Simulation based mastery learning (SBML) is a pedagogical framework that is designed to ensure competence in all learners. SBML training using a virtual environment (VE) has the potential to address individual learning differences.

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VE training can provide experience in operations such as onboard orientation and offshore emergency preparedness before crews have been deployed offshore. VEs also provide a test platform to investigate the training efficacy of new training programs before implementing them into practice.

This work presents a two-phased experiment to investigate the acquisition and long-term retention of offshore emergency egress skills attained by a SBML pedagogical approach using a virtual environment. The first phase, skill acquisition, was conducted using the SBML training approach. Smith & Veitch used the SBML framework to design virtual offshore emergency egress training [1]. The SBML training program was tested on fifty-five novice participants to assess the level of competence achieved. All participants who completed the SBML training reached the targeted performance outcomes and demonstrated competence at the end of the experimental program. The experiment established a benchmark of competent performance and corresponding times required to achieve competence. Participants were invited to return to participate in the retention phase of the experiment.

The second phase, skill retention, evaluated the long-term retention of skills attained by the same participants who completed virtual offshore egress training in those original SBML experiments [1]. The retention interval targeted for the study was 6 months. After the retention interval, participants returned to complete the same test scenarios used in the SBML experiment. The participants' performance in the test scenarios at the end of the skill acquisition phase was compared to their first attempt performance in the same test scenarios at the beginning of the retention phase. This comparison assesses the relative retention of egress skills required to evacuate an offshore platform in an emergency. Participants who failed to complete the test scenarios were retrained using exercises that focused on the particular skills they failed to demonstrate. The impact of retraining is also measured to determine how well retraining improved participants' performance in subsequent test scenarios. The goals of this work are to determine the retention of egress skills attained using the SBML pedagogical framework and to identify ways to reduce skill degradation.

Section 2 provides some background on skill acquisition and retention. Section 3 explains the methodology and data collection process. Sections 4 and 5 present the results from the retention testing and discuss the impact of retraining on the performance of individual learning objectives.

2 Skill Acquisition and Retention

Learning for mastery is a competence-based instructional framework that involves setting learning goals, monitoring progress with formative assessments, and providing feedback. The mastery learning framework assesses the learner's performance after each training unit and then guides the learner with enrichment activities or corrective exercises [2]. This is followed by further assessment before allowing the learner to advance to the next training unit. This method brings all learners to an acceptable competence standard, reduces variance in outcomes, and ensures learners have the foundation required to be successful in subsequent training units.

Mastery learning is the foundation of simulation based mastery learning (SBML), a pedagogical framework pioneered in medical education. SBML applies Bloom's mastery theory in the context of simulation training. McGaghie et al. [3] expanded Bloom's mastery learning theory to include the following principles: (1) baseline diagnostics to assess entry level of trainee, (2) defined learning objectives ordered in units of increasing difficulty, (3) opportunities for deliberate practice, (4) a minimum passing standard for each unit, (5) formative assessment and feedback to gauge progress, (6) continued practice (also known as corrective activities) on the unit until mastery is reached, and (7) proceed to next unit (also known as enrichment activities) when minimum competence in previous unit is reached.

The SBML framework was designed to ensure competence in safety-critical medical procedures [4–8]. A meta-analysis of SBML research conducted in the medical field found that SBML can take longer than other training methods, but that there is evidence of improved outcomes [6]. Training times with the SBML approach vary because the training adapts to individual learning styles and paces.

In the context of the offshore petroleum industry, regulations guide training requirements, including retraining intervals. For example, all offshore workers must do basic safety induction training before being deployed offshore. Further, they are required to exercise their emergency egress skills through routine muster and evacuation drills, typically at an interval defined by a standard or regulation. Workers who return to work after an extended period (e.g. 6 months or more [9]) are typically required to undergo safety training again, regardless of their previous experience, based on the understanding that such skills and knowledge deteriorate with time. Sanli and Carnahan [10] reviewed the long-term retention literature for safety-critical skills in the medical, military, and marine domains and found that a six-month retention interval was appropriate for complex tasks that are often taught in multi-day training programs.

3 Methods

A two-phase longitudinal experiment was conducted to evaluate the acquisition and retention of offshore emergency egress competence. The first phase involved skill acquisition using the SBML training approach; the second phase measured the skill retention after a 6 to 9 month period. This section describes the participants, the simulator environment, the methods used to deliver the SBML training, and the test scenarios used to assess the acquisition and retention of the participants' competence.

3.1 Participants

Fifty-five participants completed the SBML skill acquisition phase [1]. The participants had no prior offshore experience and were not exposed to the AVERT simulator prior to the study. All participants were invited to return to participate in the retention phase of the experiment. Thirty-six did so. The ages of the participants in the retention study ranged from 19 to 54 years, with a mean age of 29 years and standard deviation (SD) of $\pm$ 8.8 years.

3.2 Simulator

The virtual environment used to train participants in offshore emergency egress is called AVERT (the All-hands Virtual Emergency Response Trainer). The virtual emergency response trainer was modeled after an offshore petroleum platform and provided users with a first-person perspective of the working environment. The scenarios were designed to provide opportunities to practice the safety-critical procedures in credible emergency situations.

3.3 Phase 1: Skill Acquisition Using SBML Training

The skill acquisition phase involved teaching nine learning objectives using the SBML framework. Table 1 lists the learning objectives taught using AVERT. The learning objectives were taught to participants over the course of four training and testing stages.

Table 1. Learning objectives for the AVERT simulator.

No.	Learning objectives
LO1	Reach correct location
LO2	Recognize alarm
LO3	Select safest egress route
LO4	Re-route based on PA information or if path blocked
LO5	Avoid exposure to hazards
LO6	Take safety equipment
LO7	Register at the correct muster station
LO8	Avoid running
LO9	Close all fire and watertight doors

Figure 1 depicts the training and testing stages of the SBML program in AVERT. The habituation stage was used to orient trainees to the simulator controls. Each training module consisted of a series of training scenarios, followed by an assessment that was made on the basis of a test scenario. Participants were provided in-simulation instruction during the training scenarios. The scenarios allowed participants to practice and receive corrective feedback to improve their skills. Based on the trainee's performance, the trainee was either allowed to advance to the next scenario, or required to complete corrective exercises (e.g. repeat a training scenario) to address errors. At the end of each training module, participants were required to complete a test scenario successfully. This ensured the trainee reached at least the minimum passing standard at each stage before moving on to the next training module.

Module 1 taught the spatial layout of the platform and the different egress routes available from the trainee's cabin. Module 2 taught the trainees how to respond to different alarm types and the mustering procedures at the temporary safe refuge (TSR) on the platform. Module 3 taught trainees how to assess the emergency situation and to listen to the public address (PA) announcement for information on the tenability of the egress routes. Module 4 taught hazard avoidance and what to do in the event that an egress route is obstructed. Successive modules built upon the learning objectives taught in prior modules, so the scenarios tended to increase in difficulty from relatively simple muster drills to more comprehensive emergency situations.

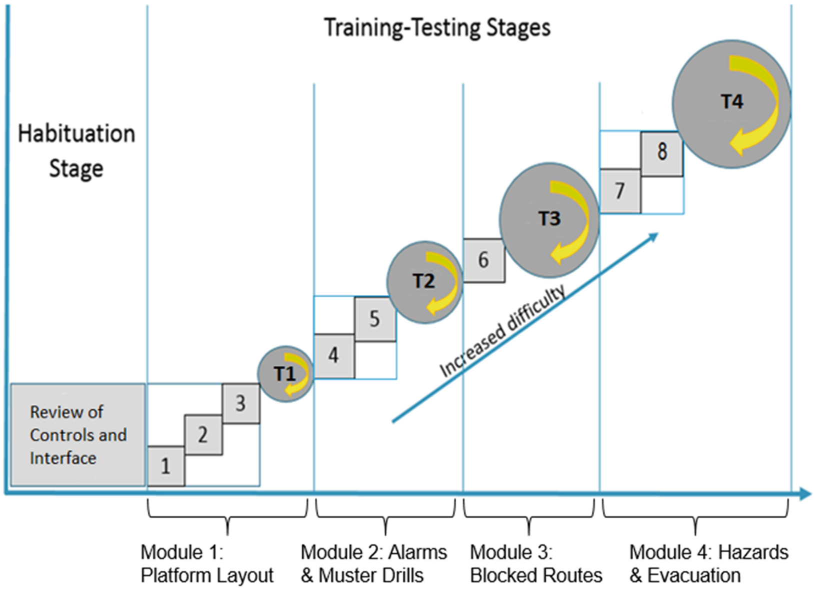

Fig. 1. Skill acquisition phase training and testing stages in AVERT [1].

3.4 Test Scenarios

Initial skill acquisition during the SBML training was assessed using four test scenarios. The test scenarios were administered after the completion of each training module. Table 2 provides a detailed description of the four test scenarios.

Participants started the test scenarios in their cabin and were tasked with responding to either a muster drill or a more difficult emergency situation. Participants had two egress routes available from their cabin (a primary and secondary route). Participants were instructed to listen to the alarm, pay attention to PA announcements, and follow the safest egress route from their cabin to their muster station or lifeboat station. In the event that their egress route was obstructed by hazards, the participants were required to use their knowledge of the platform layout to find the safest way to re-route and muster at their assigned station.

3.5 Phase 2: Skill Retention Assessment

Participants who returned for the retention part of the study did not receive any supplementary training or exposure to the AVERT simulator during the retention interval. The mean time that elapsed between the skill acquisition phase and the retention phase was 7.14 months (standard deviation = 0.87 months).

Table 2. Description of the test scenarios [1].

Test Scenario	Scenario description
T1 Wayfinding Drill	This scenario assessed the participants' spatial knowledge of the platform. Participants were asked to meet their supervisor at their assigned lifeboat station by following their primary or secondary egress routes
T2 Muster Drill	This scenario assessed the participants' understanding of alarms and muster procedures. Participants were tasked with responding to a muster drill (General Platform Alarm). During this alarm, all personnel were required to collect their safety equipment and muster at their primary muster station
T3 Blocked Route	This scenario assessed the participants' ability to deal with obstructions to their planned egress route. Participants were required to respond to the alarm, listen to the announcement, and follow the muster procedures. The PA announcements provided information to help the participants select the most effective route
T4 Emergency	This scenario assessed the participants' ability to avoid hazards and follow the safest available route to their lifeboat station. Participants were tasked with responding to an emergency involving a General Platform Alarm due to fire in the galley. The fire compromised the muster station with smoke and the situation escalated to a Prepare to Abandon Platform Alarm. Initially all personnel were required to go to the muster station, but were forced to re-route to the lifeboat station because of the compromised muster station

Participants were assessed on their knowledge of offshore emergency egress by performing the same four test scenarios that they had successfully mastered in the skill acquisition phase several months earlier. Figure 2 depicts the testing and retraining stages in AVERT for the retention phase of the experiment. Following a similar structure to the skill acquisition phase, participants were required to first complete habituation with the simulator controls.

Participants who were successful in a given test scenario advanced to the next test scenario until all test scenarios were completed. Participants who made errors in a test scenario were required to retrain by completing corrective exercises. An adaptive training matrix was used to assign the participants corrective training scenarios to address the specific errors they made. For example, a participant who failed learning objectives LO3 and LO9 in the first test scenario (T1), was required to complete one corrective training scenario that focused on teaching the available egress routes from the cabin to the muster station, and another corrective training scenario that reinforced the importance of keeping fire and water-tight doors closed during emergencies. Participants who completed the retraining exercises were required to reattempt and pass the test scenario before moving on to subsequent test scenarios.

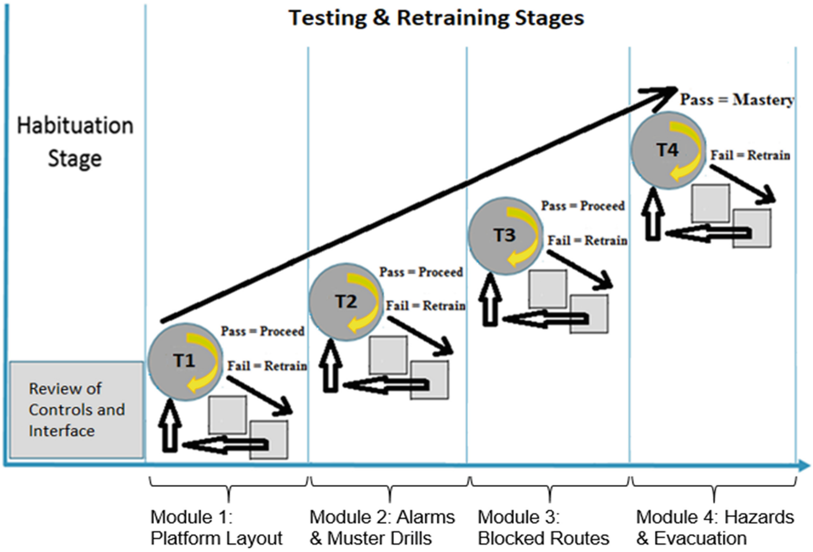

Fig. 2. Retention phase testing and retraining stages in AVERT. This shows the test scenarios for each of the modules. Participants who passed the test scenario advanced to the next test scenario. Participants who made errors in the scenario were required to retrain.

4 Results

To determine the retention of the SBML training, two indicators were used: (1) the overall performance scores in each test scenario, which represents the cohort's average competence, and (2) the performance of the participants as they first encountered each learning objective in the test scenarios. The results of the skill acquisition phase were used as a benchmark to compare with the performance scores achieved after the retention interval.

4.1 Overall Competence Retained After Retention Period

The SBML training brought all participants to competence in the targeted learning objectives during the skill acquisition phase of the experiment [1]. After a period of 6 to 9 months, 36 participants repeated the test scenarios. To measure skill retention, each participant's final (successful) attempt at the test scenarios during the skill acquisition phase was compared to the same participant's corresponding first attempt at the same test scenarios in the retention phase. A comparison of the mean performance scores for each test scenario for the skill acquisition and retention phases is provided in Fig. 3.

To compare the performance after the retention interval, a Wilcoxon signed-rank test was used. The Wilcoxon signed-rank test compares the ranked scores of two matched samples and is the non-parametric equivalent of a paired t-test [11]. A p-value of less than 0.05 was used to signify a statistical significance between the repeated measures. The Wilcoxon signed-rank tests showed a significant statistical difference

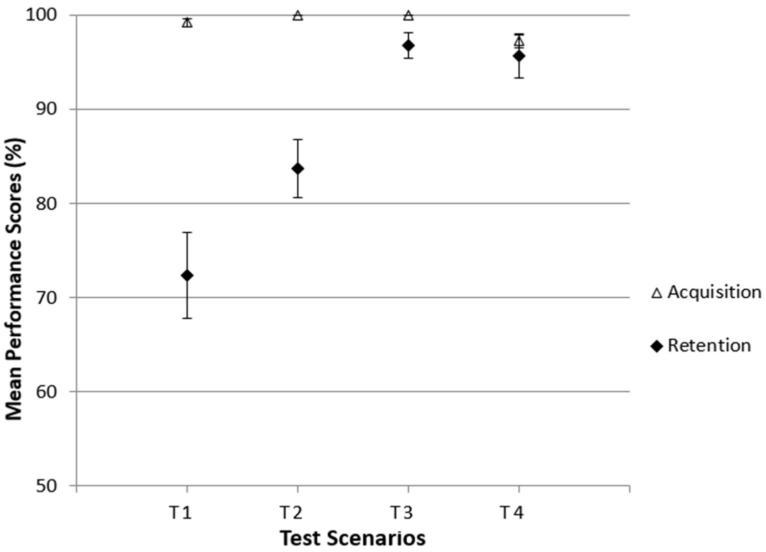

Fig. 3. A comparison of the mean performance scores at the skill acquisition and retention phases. Note: in some scenarios, the mean SBML (acquisition) performance score is not 100%. This is because all participants passed the scenario by making safe decisions, but in some cases their decisions were not necessarily the overall best choice (and this is reflected in their score).

between the performance scores from the skill acquisition and retention phases for test scenarios T1 and T2 ($p < 0.05$), and no statistical differences for test scenarios T3 and T4. Table 3 provides a breakdown of the mean scores for the skill acquisition benchmark (i.e. at the final attempt of the test scenarios), the mean scores after the retention interval (i.e. the first attempt at the test scenarios), and the p-value from the statistical test.

Table 3. Overall performance scores for skill acquisition and retention phases.

Test	N	SBML (Final attempt)		Retention (1st attempt)		Wilcoxon signed-rank
		Mean	St. Dev	Mean	St. Dev	p-value
T1	35	99.5%	2.2%	72.3%	26.9%	1.02e-05
T2	35	100.0%	0.0%	83.7%	18.0%	3.84e-05
T3	36	100.0%	0.0%	96.8%	8.0%	0.121
T4	34	97.3%	4.2%	95.6%	13.4%	0.731

Based on the average performance scores shown in Fig. 3 and Table 3, skill fade was evident in the basic wayfinding and muster drill test scenarios (T1 and T2), but not evident in the subsequent, more difficult emergency test scenarios with blocked routes and hazards (T3 and T4). In other words, based on the average performance scores, the cohort's measurable loss of skill was addressed through the combined effects of exposure to testing and targeted retraining exercises by the time they got to the third test scenario. This apparent return to competence was faster than expected. The use of average performance score as an indicator of the group's competence captures the overall trend in the experiment's results. The performance of the participants in terms of the individual learning objectives affords another lens through which to examine skills retention.

4.2 Performance by Learning Objective After Retention Period

The wayfinding scenario (T1) tested learning objectives LO1, LO3, LO8, and LO9. All three subsequent test scenarios tested these same learning objectives. Learning objectives LO2, LO6, and LO7 were tested for the first time in the muster drill scenario (T2). These learning objectives were tested again in the subsequent scenarios, T3 and T4. The blocked route test scenario (T3) tested learning objective LO4 for the first time in the retention study. LO4 was tested again in the final test scenario. The final emergency evacuation test scenario (T4) tested learning objective LO5 for the first time, as well as all the other learning objectives that had already been introduced in previous test scenarios. In terms of the retention study, it is the first time that the individual learning objectives were tested after the retention interval that is of primary interest. These were tested in a cascading format, starting at the first test scenario, where the retention of four learning objectives was assessed, to the second test scenario, where the retention of three more learning objectives was assessed, to the third and fourth test scenarios, where the retention of one more learning objective was assessed in each.

Table 4 shows the number of participants who failed each learning objective for each of the test scenarios after the retention interval. The numbers in bold represent the first time the corresponding learning objective was assessed in the retention study, which is of particular interest.

Table 4. Number of failed learning objectives in each test scenario after the retention period.

No.	Learning Objectives	Number of participants who failed			
		T1	T2	T3	T4
LO1	Reach correct location	**7**	0	1	0
LO2	Recognize alarm	–	**3**	0	1
LO3	Select safest egress route	**21**	2	4	3
LO4	Re-route based on PA or if path blocked	–	–	**4**	3
LO5	Avoid exposure to hazards	–	–	–	**2**
LO6	Take safety equipment	–	**18**	0	1
LO7	Register at the correct muster station	–	**15**	1	1
LO8	Avoid running	**14**	0	0	0
LO9	Close all fire and watertight doors	**5**	2	0	0

None of the nine learning objectives was successfully demonstrated by all 36 participants when first encountered in the test scenarios. Specifically, 7 participants failed to reach the correct location in T1, 3 failed to recognize the alarm in T2, 21 failed to choose the safest egress route in T1, 4 failed to re-route appropriately in T3, 2 failed to avoid exposure to hazards in T4, 18 did not take safety equipment in T2, 15 did not register properly at the muster station in T2, and 14 ran and 5 did not close fire doors in T1. Only 4 participants (11%) were able to successfully complete all the test scenarios without making any errors. The remaining participants failed one or more learning objectives on their first attempts. Retention appears to be weaker in terms of the performance by specific learning objectives (e.g. 11% of participants retained 100% of the skills) than when considered in terms of overall performance scores (as in Sect. 4.1 above).

The participants who failed a learning objective were provided with retraining exercises that focused on the particular errors they made. In general, the retraining exercises were effective at returning participants to competence in specific skills. For example, 14 participants failed LO8 in T1, but no one failed this skill in the three subsequent test scenarios. To say more about the effectiveness of the retraining requires we consider the performance histories of each individual, which space does not permit in this paper.

5 Conclusion

The results of this retention study have shown that emergency egress skills attained using SBML training in a virtual environment are susceptible to skill decay over a period of 6 to 9 months. Two indicators were used to understand the retention of egress skills: (1) the overall performance scores in each test scenario, and (2) the performance of participants in their first attempt at each learning objective. The average performance scores of the first two test scenarios showed evidence of skill fade. There was no evidence in the average performance scores of skill fade in the latter two test scenarios. Seven of the nine learning objectives were encountered for the first time in the first two test scenarios, so these are the most important in terms of the retention assessment. The second indicator – the performance in terms of learning objective – showed that most of the participants (89%) did not retain the full requisite skill set over the study interval. It also identified which of the learning objectives were relatively more or less susceptible to skill fade.

The majority of participants failed to remember their egress routes when they first encountered this decision in the retention study. Half the participants forgot to take their safety equipment, and about 40% did not follow the muster procedures, and forgot to refrain from running on the platform. Relatively few participants made other errors. Further, the results indicated that most egress skills that were forgotten were quickly addressed with minimal retraining. The learning objective that scored worst in terms of retention (choosing the safest egress route) also had the most persistent failures across test scenarios, suggesting that spatial competence needs relatively more training than the other skills. If these skills are lost over a 6 to 9 month period, a shorter retraining interval is required to reduce spatial skill decay.

VE training has the flexibility to provide people with practice at customized intervals, and to retrain workers who have been absent for some period. Our future work will investigate the practice and retraining frequency required to maintain emergency egress skills.

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Learning to Code and Collaborate in a Web Environment

Igor Škorić[1(✉)], Tihomir Orehovački[1], and Marina Ivašić Kos[2]

[1] Faculty of Informatics, Juraj Dobrila University of Pula, Zagrebačka 30, 52100 Pula, Croatia
{igor.skoric,tihomir.orehovacki}@unipu.hr

[2] Department of Informatics, University of Rijeka, Radmile Matejčić 2, 51000 Rijeka, Croatia
marinai@inf.uniri.hr

Abstract. Programming is a core skill that all computer science students should adopt, but mastering that skill is a demanding task. Educational institutions must find a way to alleviate problems associated with learning programming and to offer a service to an increased number of applicants. Part of these efforts is the use of Web tools in acquiring programming skills. The Web is a social platform and is designed to promote communication, collaboration, and sharing. Use of these tools in teaching programming prepares students for work in a distributed work environment but also opens up a possibility of improving learning process through new forms of interaction between students and lecturers. The aim of this paper is to provide an overview of Web programming tools with an emphasis on collaborative editors and discuss challenges they are addressing as well as possibilities of their application in the learning environment. As a follow up, a new taxonomy of programming learning tools is proposed to facilitate the comparison of these tools and selection of a suitable one for the particular learning activity.

Keywords: Learning programming · Collaborative learning
Web collaborative tools

1 Introduction

Programming forms the core of Computer Science (CS) education. It is essential that every CS student acquires programming skills. However, mastering programming courses is a difficult task for many students which is the reason why they have a low pass and high dropout rates [1, 2]. Lahtinen et al. [3] justified the set forth with the fact that programming contains numerous complex and abstract concepts. The syntax of standard programming languages is often complex and not well adapted to education [4]. Even if they master syntax of programming language, students do not know how to organize commands into a meaningful program [5]. Ben-Ari [6] points out that student often do not have an effective mental model of computers and do not understand the consequences of the execution of the commands or current state of the program. Some other factors (e.g. student motivation [7]) can also significantly affect their success in learning programming. Sorva et al. [8] summed up the students' difficulties and listed five major challenges that a student must overcome to master programming: static

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perceptions of programming, difficulties understanding the computer, misconceptions about fundamental programming constructs, and struggles with tracing of program state. These problems inspired several decades of research into the learning and teaching of programming [9]. These studies cover a wide range of topics. One of the most common topics in CS education research are programming tools [9, 10]. They represent an essential element that allows different theories, models, and techniques to be successfully applied in programming education and is therefore understandable why programming tools are important. Since the standard programming tools are not tailored to education, special tools have been developed for this purpose. Researchers have built numerous tools with the intention to facilitate teaching and learning programming [11].

The remainder of the paper is structured as follows. Section 2 describes some of the programming learning tools and gives an overview of existing taxonomies of such tools. Section 3 describes the evolution of these tools and explains why the existing taxonomy has become insufficient. Section 4 introduces and explains the new taxonomy of collaborative Web learning tools for programming. Conclusions are presented in Sect. 5.

2 Learning Programming Tools Taxonomy

The complexity of standard programming languages is one among many problems associated with programming learning all the tools for learning programming are trying to solve. The LOGO program environment [12] was developed in 1967 specifically for educational purposes. It was followed by a family of similar novice programming environments [13]. Using a series of commands, a student could draw something with a turtle graphics. In that respect, the problem that the program solved was closer and more understandable to the student. The idea that a student writes a program that solves familiar problem (like drawing rectangle) is also elaborated in programming tool 'Karel the Robot' [14]. This tool combines the simplified programming language and the environment in which the student program manages the robot movements. It was followed by several similar tools, such as 'Karel J Robot' [15] or Guido van Robot [16]. This type of tool that uses a physical metaphor to reduce the distance between the student's mental models and program concepts is commonly referred to as a micro-world [17]. The use of visual metaphors to display certain programming concepts is a technique applied in a number of programming learning tools, such as BlueJ [18], which visualizes dynamic elements of a program (variables, objects, etc.) with simple graphical symbols. Some tools use virtual worlds in which objects are created and manipulated with programming. An example of such tools is Alice [19]. Another interesting tool for learning programming is Scratch [20]. It is designed to help children learn coding, and computational thinking. With Scratch, pupils can create interactive stories, games, and animations, and programming is done by matching different pieces of the puzzle that represent commands. Verificator [21] is a tool that prevents students from making errors and helps them to learn language syntax and adopt good programming habits. The tool forces students to properly shape the program structure, to regularly check if the program contains errors and facilitates their correction. For years, researchers have created a multitude of various tools to help students learn programming [11]. Their taxonomy is briefly explained in the following sub-section.

2.1 Taxonomy of Learning Programming Tools

To organize a wide variety of tools that can help in the acquisition of programming skills we have to somehow categorize them. In survey of tools for learning programming [22] tools are classified into the following four groups:

- *Programming environments* - Allow students to experiment with specific features of programming language and are used in program construction, compilation, testing and debugging.
- *Debugging aids* - Used by programmers to test programs, observe program behavior during execution, detect, and correct errors.
- *Intelligent tutoring systems* - Allow access to tutoring and testing material, offer adaptive instruction, analyze student responses, determine correctness, and provide feedback and advice based on stored expert knowledge.
- *Intelligent programming environments* - Combine features of intelligent tutoring systems with tools used in problem-solving and program development process.

In the survey of literature on the teaching of introductory programming [23] authors have pointed out other categories:

- *Visualization tools* - Show certain aspects of program dynamics through visual metaphors.
- *Automated rating tools* - Allow students to submit their programs, and give them a rating. These tools most commonly use pre-prepared test cases to check whether the program runs correctly.
- *Programming environments* - Different form of integrated development environment specifically adapted to the educational context
- *Other tools* - all other tools that do not belong to the previously described group

Although this taxonomy clearly classifies tools into different groups, it is not sufficiently detailed. Programming learning tools are created with a clear goal to facilitate learning a certain aspect of programming using a specific approach. In that context, when we want to select a particular tool, it is important to understand which problem it solves and in what manner. In order to understand the purpose and nature of the programming tool extensive taxonomy was developed by Kelleher and Pausch [11]. In their taxonomy, tools are categorized in two main groups: teaching systems and empowering systems. The first group consists of "systems that attempt to teach programming for its own sake" and second group of "those that attempt to support the use of programming in pursuit of another goal" [11]. Each group is further decomposed by the primary aspect of programming that the system attempts to simplify (e.g. expressing programs). In addition, each aspect is parted into a sub-problem that it solves, and each sub-problem is decomposed into the techniques by which it is solved. Each tool can appear in the taxonomy only once, based on its primary goal. This can lead to a situation where a tool that is based on solving multiple problems is only in one group, or that two similar tools are placed in different groups.

Some studies in the field related to only one set of programming tools. In this context, more authors explored the use of visualization tools in learning programming. Under the influence of the study [24] which links the success of using visualization tools and student engagement, taxonomy with five levels describing the extent of students' engagement when using visualization tools was introduced [25]. The aforementioned taxonomy describes the following levels of engagement: no viewing, viewing, responding, changing, constructing, and presenting. Study [26] presented extended engagement taxonomy (EET) in which four additional levels (controlled viewing, entering input, and reviewing) were introduced. Building on the set forth research, study [27] developed two-dimensional engagement taxonomy (2DET) that relates the direct engagement that the student has with visualization and content ownership. Levels in engagement dimension are similar to those in the EET, and levels in ownership dimension are: given content, own cases, modified content, and own content. The taxonomy was used as a classification tool for describing the visualization tools.

In [28] authors proposed three-dimensional taxonomy of Web 2.0 applications with educational potential. Proposed dimensions are: type (wiki, blog, microblog, social network…), function (collaboration, sharing, communication, knowledge organization, learning support, and artifacts integration) and cognitive processes (remembering, understanding, applying, analyzing, evaluating and creating). Although it is intended for education in general, it can be applied to learning programming as well.

3 Evolution of Learning Programming Tools

Difficulties that novices have with fundamental programming concepts encourage further research in CS education area. New studies are looking for innovative approaches, techniques, and tools that will alleviate learning. Some of the research strategies show the potential to improve the learning outcomes of programming. For instance, study [29] listed pair programming, peer teaching, and media computing as examples of such successful approaches. They have concluded that these three approaches help students to learn and retain knowledge and that their combination improves the effect. In [30] authors explored the effects of thirteen different approaches to teaching programming. Based on the analysis of primary studies, they concluded that pedagogic interventions based on collaborative learning (cooperative learning, team-based learning, and paired programming) have shown biggest improvement in learning outcomes. Research [31] found that the simultaneous use of three techniques of active learning (media computation, pair programming, and peer instruction) significantly improves students' results in the introductory programming course. Such results have contributed to the broad acceptance of collaborative techniques in learning programming, and the adoption of these techniques has created a need for tools that comply with this way of learning. Another important factor influencing the development of the learning tools is technology. The appearance of the Web 2.0 with Ajax technology, HTML 5 and JavaScript enabled the emergence of a new platform. Web environment offers many advantages over desktop [32]: unique interface always available from anywhere, instant collaboration, and easy integration with other services. Users do not need to worry about installing, maintaining, and updating. Today, we can find numerous development tools as Web services. Some of these tools are not created with the idea of being used in education. For example, CoderPad[1] was created for conducting programming interviews but can be used for real-time collaborative programming in education. Some programming environments such as CodePen[2] or repl.it[3] have no primary educational goals, and some as Codewars[4] are made solely for educational use. Some of these tools are simple such as Ideone[5], and some are complex integrated Web-based development interfaces such as Codeanywhere[6] or Cloud9[7]. These products do not have all the capabilities of their desktop counterparts but support complete process of software development on the Web. This trend of adding collaborative elements and a gradual transition to the Web platform is followed by all other programming tools. Different tools use different approaches. Codeboard[8] is a combination of Web-based IDE with elements of learning management system. CodingBat[9] besides the Web environment also includes prepared problems on which students can practice. Code Hunt[10] is a combination of program environment and video game.

Web is designed to enable communication, collaboration, and sharing. For tools in such an environment, it is natural to contain the social features. Development of distance learning and the popularity of Massively Open Online Courses (MOOCs) also contributed to the popularity of the Web. Collaboration and feeling of community are important for MOOCs to be effective [33]. Collaborative functionalities of a tool are also desirable in face-to-face learning. They allow a smaller number of teaching staff to provide education to a larger number of users.

The integrated development interface (IDE) has also changed considerably over time. Different integrated development environments have different capabilities and different toolkits, but they all contain editor, compiler, and debugger. That set of tools represents a minimum which is sufficient to a programmer to create a program. At the beginning of IDE evolution, new features were added that facilitated the programmer's work (e.g. coloring the code). All that time, the main purpose of IDE was to improve individual performance of a programmer. As software development over time grown complex, it became less the result of an individual's work and more frequently the outcome of the work of the whole team of specialists.

Collaboration is today a key element in software development because it significantly contributes to the project's performance [34] and development team members spend a

[1] https://coderpad.io/.
[2] https://codepen.io/#.
[3] https://repl.it/.
[4] https://www.codewars.com/.
[5] https://ideone.com/.
[6] https://codeanywhere.com.
[7] https://c9.io.
[8] https://codeboard.io/.
[9] http://codingbat.com/java.
[10] https://www.codehunt.com/.

significant amount of time on employing it. Moreover, nowadays it is not uncommon that the team members are dislocated. It is about a distributed software development where the challenge of achieving successful collaboration among team members is difficult. To make this collaboration among members of the development team as easy as possible, numerous tools are used. Some of these tools are common, widely accepted communication tools such as e-mail or instant messaging (IM), while other tools are specifically created to support software development such as the version control systems (VCS). In time, collaboration and communication tools have been embedded in integrated development environments such as Visual Studio[11]. The integration of collaborative tools with development tools allows developers to stay all the time in the same cognitive context (as they do not leave the environment). Such tools designed to improve the overall development team's performance are called collaborative development environments (CDEs) [35]. Today, almost all software development tools have collaborative functionality. IDEs created for professionals are often not suitable for learning as the amount of their functionalities can easily overwhelm the student. Learning tools must be easy to use and understandable. Their characteristics must be carefully chosen to match the pedagogical approach and type of education. With an objective to address this issue, we proposed a novel taxonomy that will be presented in following section.

4 Taxonomy of Collaborative Tools for Learning Programming

Programming education goes through the constant changes and tools we use in that respect follow these changes. On the one hand, the popularization of new pedagogical techniques (collaboration, peer learning, etc.) and on the other hand technological progress, led to the emergence of new tools drawing on Web 2.0 platform. Active and collaborative learning techniques encouraged the development of tools that facilitate student engagement in the learning process, their cooperation, and mutual communication. The Web platform facilitates this transformation. Novel tools should respect the nature of the Web environment and should therefore include sharing, collaboration, and communication functionalities. All the aforementioned challenges the appropriateness of using existing taxonomies for that kind of tools.

4.1 Can We Use Old Taxonomy for New Tools?

Taxonomy is a system of classification used to organize concepts into a framework for discussion or analysis. With taxonomy we can name, describe, and classify concepts on the basis of shared characteristics. If the result of our work is the taxonomy of programming learning tools, it should classify these tools by the properties that are essential to us for use of these tools. Taking into account that no single learning programming tool can address all tasks, taxonomy should help us to choose the right tool for our problem.

For example, we will take the LogoBlocks program [36], which was in a taxonomy developed by Kelleher and Pausch [11] classified in a group of tools that students can

[11] www.visualstudio.com.

use to construct programs by using objects. Let us imagine a similar Web tool that, besides the described functionality, also allows students to share the results of their work with others, and in which programmer can chat with other colleagues and other students can watch how he creates a program through a shared screen. This new tool in taxonomy introduced by Kelleher and Pausch will be in the same group as LegoBlocks. Two tools that differ significantly would be placed in the same group. Although described taxonomy has well-defined groups, due to the limitation that the tool can be in only one group, it is inadequate to describe them completely. The Web tool allows students to collaborate, and interaction is an important component of the successful collaboration. Since research [24] demonstrated that student engagement levels are positively correlated with the amount of interaction, we must also consider it as dimension. Kelleher and Pausch omitted that element in their taxonomy but dimension of engagement is part of visualization tools taxonomies [25–27]. The next important factor to take into account is the nature of communication that can be achieved through that tool. The nature of communication is complex because it can be, on one hand, synchronous or asynchronous, as well as visual, vocal or textual, on the other one. In that respect, the same tool can support many different forms of communication. Depending on whether we plan face-to-face or distant learning, synchronous or asynchronous communication, we will select a tool that supports communication that is appropriate for the planned activity type.

4.2 Proposed Taxonomy

Since different types of tools can have completely different requirements, we will only limit our study to Web based integrated development environments. In taxonomy developed by Pears et al. [23] these tools belong to the group of programming environments. They are the core tools for learning programming and most of the time in CS courses students are working with such tools. The purpose of this taxonomy is to classify these tools in a way that enables the lecturer to choose the optimal tool for a type of pedagogical activity (s)he plans to use in the course. We assume that some of the collaborative learning techniques will be used as well since in that manner the advantages of these Web tools can best come to the fore.

The proposed taxonomy (shown in Table 1.) consists of three dimensions. The first one is the type of help which describes how a tool assists the student to create a program. This dimension corresponds to the fourth column in the taxonomy developed by Kelleher and Pausch [11]. As one tool can assist the student in several ways, it can be assigned to several types of help. The lecturer can choose the tool based on the help that is the most suitable for students. The second dimension is communication which describes the types of communication students can achieve through the tool.

With this dimension, the teacher with respect to the type of planned activity (face to face, distant, synchronous, or asynchronous) selects the tool that best suits his/her needs. When choosing a communication method, students' preferences may also be considered.

Table 1. Taxonomy of Web programming environments

Dimension	Values
Type of help	Simplify the Language Prevent Syntax Errors Construct Programs Using Objects Create Programs Using Interface Actions Provide Multiple Methods for Creating Programs New Programming Models Making New Models Accessible Tracking Program Execution Make Programming Concrete Models of Program Execution Solve Problems by Positioning Objects Solve Problems Using Code Demonstrate Actions in the Interface Demonstrate Conditions and Actions Specify Actions Make the Language More Understandable Improve Interaction with Language Integration with Environment
Communication	Chat Video Audio Forum Blog Wiki Social network Blackboard …
Engagement	No viewing Sharing Viewing Communicating Changing

The third dimension is engagement which corresponds to the dimension of the same name in the taxonomy of visualization tools. One or more values can be included in this dimension:

- no viewing - every student can see only his/hers workspace
- sharing - every student can see only his/hers workspace, but can share his/her work with peers
- viewing - student can see workspace of other students or teacher
- communicating - student can see workspace of other students or teacher and can communicate through a tool
- constructing - a group of students can jointly create a program by using a tool

Each dimension allows us to evaluate one of the aspects of tool suitability. The first dimension allows us to assess whether the tool corresponds to the student's experience or age. Within this dimension we describe all the ways in which the tool provides assistance and this allows us to select very precisely the tool that best suits the planned activity. Beginners are geared to tools that offer more help. Some types of help are more suitable for younger students, so the 'Create Programs Using Interface Actions' option would be suitable for elementary students, and the 'Create Programs Using Interface Actions' option would be appropriate for preschool age.

The second dimension determines the way of communication. If we plan face-to-face activity, we will select tools that support asynchronous communication. In the case of distance learning depending on the planned type of activity, we will select the appropriate type of communication. It can appear that a tool does not incorporate communication functionality but still can be used in collaborative learning settings. In this case, the tool is limited to face-to-face teaching where communication among students is carried out in the form of verbal interaction. The third dimension determines the level of engagement of students we want to achieve during our activity. Let's say we want to inspect the code with the students. If we want the lecturer to show and explain the code in the classroom, and students should just listen, we will select a tool with 'no viewing' attribute. If we want students to download the program code on their computers, the tool must support the 'sharing' option. If we carry out the same activity in distance learning environment, the tool must support the 'viewing' option, so students can see code on their computers. If we want students to change the code being viewed then the level of engagement supported by the tool must be 'changing'.

Table 2 shows a description of three tools (ideone.com, CodeShare[12], and Code hunt) using the described taxonomy. From the first dimension we can see that ideone.com and

Table 2. Example of tool categorization

Tool	Dimensions		
	Type of help	Communication	Engagement
ideone.com	Prevent Syntax Errors		Sharing
CodeShare	Prevent Syntax Errors	Video Audio	Sharing Viewing Constructing
Code Hunt	Prevent Syntax Errors Construct Programs Using Objects Tracking Program Execution Solve Problems Using Code	–	No viewing

12 https://codeshare.io/.

CodeShare are intended for similar audiences - students who do not need much help. In other two dimensions, these tools differ significantly. Ideone.com does not support any form of communication so it is only suitable for individual work or face-to-face group work. On the other hand, CodeShare supports audio and video communication that can be useful in remote learning. CodeShare also supports multiple levels of engagement, so it can be used for different types of activities (e.g. group code inspection or collaborative programming). Code hunt is as can be seen from a table intended for a completely different audience. It would probably be the most suitable for elementary school children because of the numerous elements of help. In addition, it does not contain any communication or engagement functions, so it is only suitable for individual work.

5 Conclusion

The tools for learning programming are one of the most important topics in computer science education research. The development of these tools is conditioned by two factors. The first one is the progress in the pedagogical interventions we use in education, and the second one is technological advancement. Tools are just a means to implement a particular strategy, model, technique or technology, and how new strategies, new models or techniques are emerging, and new tools are being developed as well. Previous studies show that the techniques that encourage student's engagement and their collaboration improve the learning outcomes of programming courses. This has led to the development of tools that support such forms of learning. The transition to the Web platform has further facilitated the development and increased the popularity of such tools. In order to achieve the optimum effect of education, it is necessary to carefully select the appropriate tool that best suits the chosen pedagogical technique. In this study, we have proposed taxonomy of Web programming environments whose aim is to alleviate a choice of tool that best suits the planned learning activity. The proposed taxonomy allows the classification of tools based on three simple dimensions that indicate whether the tool is suitable for a particular situation.

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Small World Networks in Education Sciences

Miguel Arcos-Argudo[1,2,3(✉)], Fernando Pesántez-Avilés[1,2,3(✉)], and Diego Peñaloza-Rivera[1(✉)]

[1] Rethinking the Education – Educational Innovation Group, Salesian Polytechnic University, Cuenca, Ecuador
{marcos, fpesantez, dpenaloza}@ups.edu.ec
[2] Research Group on Artificial Intelligence and Assistance Technologies (GIIATA), Salesian Polytechnic University, Cuenca, Ecuador
[3] Cátedra UNESCO – Education for Inclusion, Salesian Polytechnic University, Cuenca, Ecuador

Abstract. Networks with a small world topology are distinguished by the characteristics of their connections, allowing two nodes, distant from each other, to be linked by a shorter path. This work relates the concept of small world network in the area of Education Sciences in particular in the integration of teaching cloister in the world system of higher education. A relation is established with micro-world and nanoworld concepts defined in previous works and the term of constellations of small worlds is defined, which allows to group subsets of the network that we analyze. It is concluded that the concept of small world network can be understood in the integration of teaching cloisters to the world system of higher education, which would allow to increase the quality of teaching and research work in Latin America.

Keywords: Small worlds networks · Micro-worlds · Nanoworlds Higher education · Small worlds constellations

1 Introduction

In our environment, we coexist with several systems whose elements are related to each other, for example, the transportation system of the city in which we live, the banking system in which we conduct our financial transactions, the website where we make personal purchases, among others. These systems have become part of our daily life, in such a way that it is likely that in some cases we will interact with them without thinking about the structure of the relationship maintained by its components. This relationship can be represented by graphs in which, in some way, it can be seen that its structure can be understood as a type of network. In this great diversity of network types that exist in our environment exists one called *small world network* introduced by Watts y Strogatz [1]. This concept has been widely used to study many systems in which it can be concluded that its structure has a small world topology, studies have been deployed in areas such as: social networks [2–4], electrical networks [5, 6], pandemics [7, 8], neurosciences [9, 10], etc.

The Salesian Polytechnic University (UPS), in the search of its academic excellence, where the teaching task must be dynamic and be strengthened by the cooperative

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work between peers, has managed to develop connections that favor the constitution of *teaching cloisters*, which they consist of the grouping of professors in scientific domains, thus ensuring coherence between related subjects and the academic profile of the teacher. The members of each cloister, plan the development of the subject, develop support material that will be used in the teaching-learning process, design cooperative virtual environments, all from the synergy of information and experiences; This process is intended to establish a common didactic model, with homogeneous methodologies and consensus evaluations. Each cloister of the UPS represents a node of the network, however, they are not isolated nodes, since the teachers of each cloister maintain permanent contact with other cloister and in turn with professors or teaching groups of universities from different parts of the world; these contacts correspond, in the majority of cases, to doctoral thesis tutors, therefore, it is normal that the UPS teaching cloisters create links or short routes, with teaching and research groups from other universities physically located at a greater distance; through these links, forming a network with a small world typology, all the teachers of the cloister, and the teachers of the other cloisters, can access and enrich themselves with the experience, not only of their local colleagues, but also with the experience of the foreign teachers and researchers with whom they are related; in the same way, foreign teachers can exchange knowledge, material, information and experiences with UPS teachers. This work also relates the analogy posed with concepts of micro-worlds and nanoworlds defined in previous works by researchers from the UPS. Finally, the concept of constellations of small worlds is proposed, which allows to group nodes of the network that we analyze and that have great affinity in the work they do.

2 Small World Networks: Basic Definitions and Notation

The following concepts and definitions are important for the understanding of this work.

A *network* is a finite set of nodes and edges. An *edge* represents a relationship between a pair of nodes of the network. Figure 1 shows a graph that could be an illustration of a train transport system in a city, in which each point named with a letter can represent a stop station, and each line joining a pair of points can represent the path of a train line from a source station to a destination station, for example, there is a path without intermediate stops between station A and station H, therefore, in this graph there is an edge between node A and node H and we denote it as AH, we also say that node A is neighbor of node H.

A *path* between a source node v_1 and a destination node v_2 is the sequence of nodes that must be visited within the graph to move from v_1 to v_2, it is denoted as v_1v_2-path. For example, in Fig. 1 exists a path from source node A to the destination node V. where $AV\text{-}path_1 = A, H, C, V$, however, this is not the unique way between these nodes, since there is also the path $AV\text{-}path_2 = A, H, I, J, K, L, S, U, R, D, E, Z, W, V$, there are also other paths between A and V. The *distance* or *path length* is the number of "jumps" required to travel from a source node to a destination node, for example, the distance between A and V in $AV\text{-}path_1$ is 4, while the distance in $AV\text{-}path_2$ is 13.

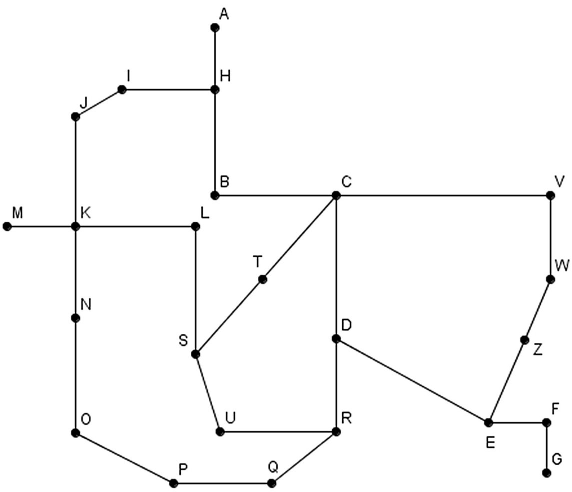

Fig. 1. Illustration of a network.

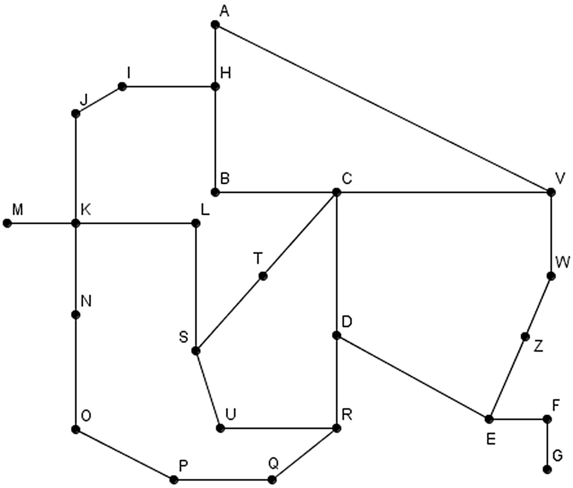

Fig. 2. Illustration of a network where the edge AV has been created.

A *small world network* is a network type introduced by Watts and Strogatz [1], the topology of this network has the characteristic that given a network R, in which there exist nodes v_1 and v_2 such that $v_1 \neq v_2$, related by a ph v_1v_2-$path_1$ with length $d > 1$, it is possible to establish an edge v_1v_2 in R such that it defines a network R' that contains a path v_1v_2-$path_2$ whose length is equal to 1 [11, 12]. Therefore, in R' will exist a path with the minimum length between two different nodes. A network in which these paths may occur is called *small world network*. For example, in Fig. 1 the minimum distance between A and V is 4, but Fig. 2 shows a network in which an edge AV has been created, therefore, there exists a AV-*path* whose length is 1.

The *degree of a node* is the number of edges that a node v_1 has in a network, and we denote it as $g(v_1)$, for example, in Fig. 1, $g(A) = 1$ while $g(K) = 4$. The higher the degree of a higher node will be its importance in the network, because it will be connected with a greater number of neighboring nodes. For example, if in Fig. 1 we eliminate the node K then the edges KJ, KL, KM and KN also disappear, in addition the node M would be isolated from the other nodes.

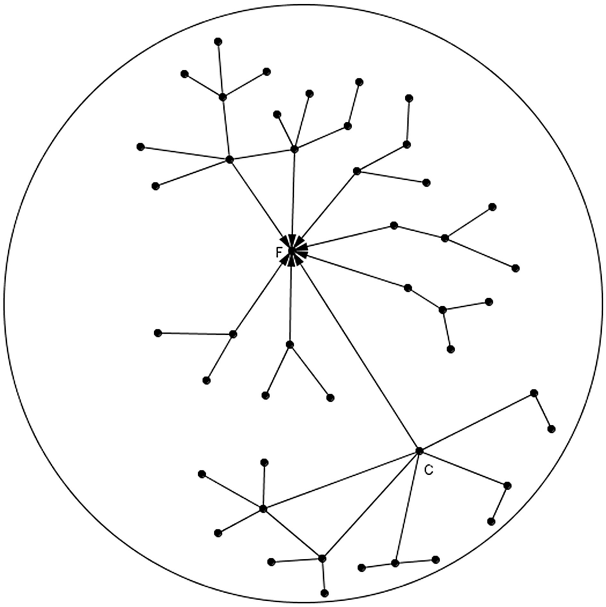

Fig. 3. Illustration of a social network with topology of small world network.

2.1 Importance of a Node According to the Degree of Its Neighbors

The importance of a node in a network can be measured according to its degree, however, within a network with small world topology, the importance of a node can also be measured according to the degree of its neighbors. In the graph of Fig. 1 we can see that degree $grado(M) = 1$, however, its only neighbor node K has the highest degree in the network ($grado(K) = grado(C) = 4$), then, node M acquires, in some way, a certain level of importance within the graph thanks to its neighbor.

We can imagine an ordinary person who, in general, will not have much chance of approaching a celebrity like a famous football player, a movie star or the president of a nation; however, in the environment of a social network this reality can change drastically; Normally this common person will not have a high number of followers, but it is very likely that he is a follower of a world famous celebrity; as well as it is probable that this celebrity has a quite high number of followers. Figure 3 shows an illustration of a scheme of a social network; in it the node C represents an ordinary person with a low number of followers, however it follows a possibly famous person (node F), hen it is said that node C has approached node F.

Another way of conceiving a small world network is through the relationship that may exist between the subsets of a network. We can imagine a finite set of *"farms"* in which the members of each one maintain a relationship with each other except for some that may be connected to members of another farm. In Fig. 4 we can see a set of nine farms in which the farm f_0 is directly related to five "smaller" farms, and indirectly with three others, for example, the farm f_7 is related to f_0 through the path $f_7 f_0$-$path = f_7, f_8, f_0$. It is notorious then the importance of the farm f_0 in this graph, then, the more members of a farm have relationship with members of another farm, the more important the farm will be in the network.

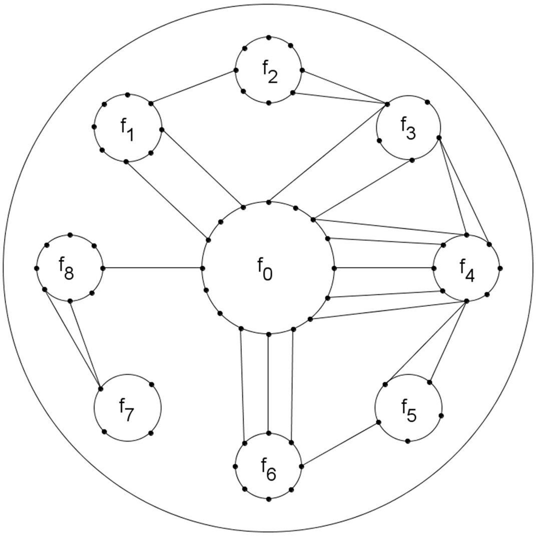

Fig. 4. Illustration of a small world network formed by farms.

3 Teachers' Cloisters, like Microworlds, Nanoworlds and Constellations of Small Worlds

On the one hand, social reality is a complex system of interrelations. The educational spectrum does not escape this consideration, so that in order to understand it, administer it and model it, man needs to break it down into smaller but equally complex parts.

Taking the education system of a nation as an example, these segments can be the educational levels that make it up. At each level, it is also possible to decompose it from the functions that articulate it; in all cases, their structures maintain characteristics of complexity.

On the other hand, for each human being their conception of education as well as other concepts such as culture and reality, are different, in all cases they respond to their own experiences, knowledge and abilities, and they are also directly dependent on the context in which they develop, in that sense we would say that each person has the opportunity to model their world and that this is finally the sum of smaller but equally complex segments. These segments have a fractal logic, that is, they reproduce their structure and complexity, for Pesántez [13], these segments are called micro and nanoworlds. For this work this concept is adapted to small worlds.

From the previous considerations, educational constellations mediating small worlds are understood as multiple-scale learning support ecosystems, which use microworlds and interactive nanoworlds [14], which through different processes strengthen at the level of conglomerates -teaching cloisters- educational competences to achieve. Thus, the teaching-learning exercise constitutes the nanoworlds of each teacher; the university functions of teaching, research, linking with society and administrative management would represent the microworlds, while the projects that these interactions give off would be the constellations of small worlds.

3.1 The Teaching Cloisters as Network Nodes

A nanoworld, as an individual teaching-learning exercise for each teacher where the task must be dynamic and strengthened by cooperative work among peers, must lead to the development of connections that favor the formation of teaching cloisters, which consist of the grouping of professors in scientific domains. This ensures coherence between related subjects and the academic profile of the teaching staff, as well as enhancing their research and specialization skills.

The members of each cloister, plan the development of subjects, develop support material that will be used in the teaching-learning process, design cooperative virtual environments, all from the synergy of information and experiences; This process is intended to establish a common didactic model, with homogeneous methodologies and consensus evaluations.

Each cloister of the UPS represents a node of the network, however, they are not isolated nodes, since the teachers of each cloister maintain permanent contact with other cloisters and in turn with professors or teaching groups of universities from different parts of the world; these contacts correspond, in the majority of cases, to professors with doctoral degrees, therefore, it is normal that the teaching cloisters of the UPS create links or short routes, with teaching and research groups from other universities physically located at a greater distance.

Through these links, they form a network with small world topology, all the teachers of the cloister, and the teachers of the other cloisters, can access and enrich themselves with the experience, not only of their local colleagues, but also with the experience that the foreign teachers and researchers with whom they relate have; in the same way, foreign teachers can exchange knowledge, material, information and experiences with UPS teachers.

From this explanation, we assert that the personal reality is also a micro or nanoworld that converge at some point in educational constellations, insofar as they constitute "communities of practice" Wenger [15]. Where learning maintains meaning within a process of collective and community commitment, in this case participation is about the social practice of education, in other words, social learning is generated that generates resources thanks to the interaction of the members of the local and global university community.

The 4 premises of Wegner regarding the social theory of learning are fulfilled in the constellations of small worlds, thus: (a) each member is conceived a social being; (b) knowledge is a matter of competence; (c) there is an active commitment to be valued as members of a university community; (d) the meaning of their identity is what motivates their exercise. From what has been described, micro and nanoworlds as learning development elements are designed, at an individual level as a member of a higher education institution, to reinforce the practices of university functions, reaffirming them; and at the organizational level to keep their conglomerates integrated.

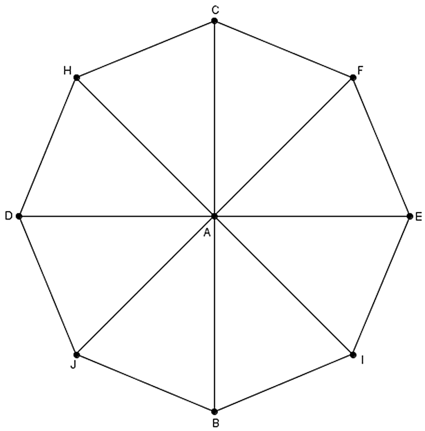

Fig. 5. Example of the structure of a teaching cloister.

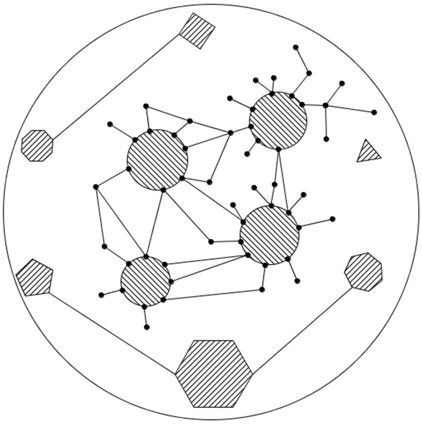

Fig. 6. Example of relationship between teaching cloisters.

4 Small World Networks Conformed by Teaching Cloisters

In the previous section, we can see that a teaching cloister works if there is a group of professors that interact with each other in order to obtain material and define common methodologies that benefit the development of their teaching activities. It can be said then that a teaching cloister can be represented with a graph whose network structure is strongly connected [16], that is, each cloister member is "connected" or maintains a relationship with all other professors, Fig. 5 shows an example of the structure of a teaching cloister.

Now, consider all the groups of teaching cloisters that exist in the UPS. In view of the fact that each cloister specializes in a very specific area of knowledge or subject, then there are very few relationships between teachers of different cloisters, this case would be given, for example, if a teacher member of a cloister advises or shares material with a teacher from another cloister, in this sense, there will not be many teachers who have relations with teachers from other cloisters. In Fig. 6 the existence of six teaching cloisters (represented by regular striped polygons) and the scarce relationship between them are illustrated, in addition, the resulting graph could be non-connected. The striped circles represent teachers or groups of teachers from other universities.

However, the teachers of each cloister, in the course of their profession and their fourth level academic training, have had the opportunity to establish strong links with teachers from other prestigious universities, for example, if a teacher is studying at Harvard University, he will most likely maintain a link with at least the tutor of his thesis; considering that the UPS teacher needs to specialize in the academic area than his subject, then all cloister members of the cloister are probably interested in the subject. In this way, a teacher from the UPS, and all the teachers of his cloister, maintain a *"short path"* with a Harvard University professor located geographically far away and at a much higher ranking, which benefits his work since have the opportunity to enrich themselves with experiences raised in other places of the world. If we establish these relationships in the graph of Fig. 6 the result would be a graph with a structure of small world network (Fig. 7).

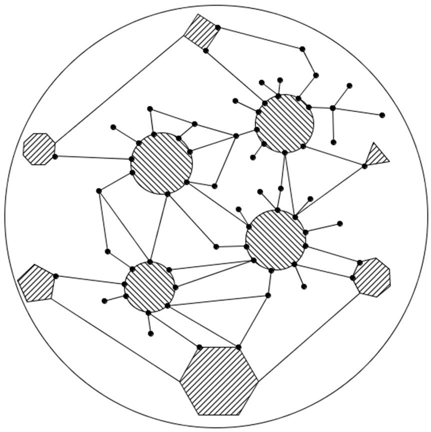

Fig. 7. Illustration of a small world network built through the relationship of teachers' cloisters with other universities.

5 Conclusions

The concept of small world networks allows to understand the interaction of two elements of a network in a direct way when they are physically or logically located at great distances. The teaching cloisters allow the UPS to improve the teaching-learning process because it brings together teachers with common scientific domains to plan the development of the subject, develop support material, design cooperative virtual environments, with the intention of establishing a model didactic, with homogeneous methodologies and consensual evaluations, with this the UPS manages to have a coherence between related subjects and the academic profile of the teacher. The integration of teaching cloisters into the world higher education system allows for direct links with prestigious professionals and research groups, which helps to enrich their experience and resources. The direct relationship between UPS teaching cloisters and the important elements of the world education system can be understood as a small world network.

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Design, Implementation and Efficiency Analysis of the Special Degree Unit as an Alternative for the Graduated Students' Degree: UPS Case

Miguel Arcos-Argudo[1,2,3](✉) and Fernando Pesántez-Avilés[1,2,3](✉)

[1] Research Group on Artificial Intelligence and Assistance Technologies (GIIATA), Salesian Polytechnic University, Cuenca, Ecuador
{marcos, fpesantez}@ups.edu.ec
[2] Rethinking the Education – Educational Innovation Group, Salesian Polytechnic University, Cuenca, Ecuador
[3] Cátedra UNESCO – Education for Inclusion, Salesian Polytechnic University, Cuenca, Ecuador

Abstract. The little effectiveness of the degree systems in higher education is not an isolated problem in the long list of the university tasks, to be better understood, it has to be referenced to complementary processes, such as the access and the permanence into the system. To favor students get their degrees, in Ecuador, the Higher Education Committee, promoted in 2013 the implementation of Special Degree Units in each institution of higher education (IES). In this article, we share and demonstrate the experience of the Salesian Polytechnic University regarding the implementation of its Special Degree Unit (SDU). It has allowed young "university students with no degree" to get it as professionals. It is concluded that the 80% of the students who, according to the regulations, could be embraced into this Unit, got their degree, through a more effective instrument, which was the Degree Completion Exam.

Keywords: Special Degree Unit · Under graduate students
Professional degree · Completion exam · Thesis work

1 Introduction

The little effectiveness in the degree systems in higher education is not an isolated problem in the long list of the university tasks; to confront it, it is not possible to stop mentioning the education system in its integrity. In this sense, the graduation and degree systems cannot be seen separately into the education reality regarding access, permanence, and even the professional practice. It is known that being enrolled, stay, and successfully graduate from the education system allows the participation of the people in scientific, technological, and innovation actions; for this reason, this is the ideal way to evidence the negative consequences of exclusion by means of not getting a professional or university degree [1].

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In the document Metas Educativas 2021 [2], which refers to the expected education for the bicentennial generation, we find in the analysis that corresponds to the poverty and vulnerability, from inequality, exclusion, and inter-generational transmission of the education opportunities, the following aspects:

Moreover, education represents an essential factor for the perception that people have from their own inclusion. Transversal to the different socioeconomic groups, a person having a degree, is considered the most relevant option at the time of being part of society. Higher education is the third most mentioned alternative. In this way, the relevance of education is evident not only objectively, as its importance in the households' stratification, but also in people's perception of what it means to be included in society [2].

The previous paragraph remarks the relevance that the social order of higher education has in order to ensure the quality of its services, including a social vision responsible for the qualification of its students. We must be aware of what it represents for a human being from the logic of social inclusion, to enter and successfully graduate from the higher education system.

Globally, access to higher education is an increasingly reduced possibility for the population, among several causes this can be attributed to the high economic costs of studying a career to obtain a third level degree [3]. However, the existence of a very large number of people who have managed to complete all their studies except for the research work has been evidenced (previously called graduation research project), therefore they have not got a degree, according to the authors [4] it is a type of students' desertion. For the Salesian Polytechnic University of Ecuador (UPS) this group of students are called under graduate who are a social capital with great potential, however this possibility is affected by not getting a professional degree that allows them an insertion with better perspectives in the workplace and community, so the Salesian Polytechnic University offered these people several alternatives to develop their research work and to incorporate them as professionals.

The Tecnológica Equinoccial University (SDU) is the most important mechanism that the Higher Education Institutions in Ecuador have had, since the issuance of the Academic Regime Regulations [5] offer non-graduates an option to achieve their third level degree. This mechanism included a complex degree examination with two different research topics for each degree. This paper summarizes the design, implementation, and efficiency analysis of the (SDU) based on the results of graduates' students in the UPS.

2 The Special Degree Unit

In the Salesian Polytechnic University (UPS) the Special Degree Unit (SDU) has been responsible for organizing the qualification processes of students typified under this figure in the Academic Regulations of Ecuador Higher Education Council - CES [5, 6], through the academic planning from the areas of knowledge, and workability in degree programs through their respective special degree Coordinators. The fundamental result of the SDU is the development of a research work, based on investigation and intervention processes or the preparation and approval of a degree exam [7].

2.1 The Special Degree Unit (SDU) Design and Implementation

A Special Qualification Coordination team was structured for each degree course. This team defined the types of degree work in coordination with the areas of knowledge, organized and executed the courses, workshops, completion exams and tutorials for all students involved in this certification process [7]. SDU has been articulated through a set of selected subjects after diagnosis of the problems, axes, processes, dilemmas or situations that constitute the object of professional training. These subjects have been oriented to design and strengthen the degree work [7].

One of the graduation options offered to the graduates has been the completion exam, consisting of an evaluation that has been applied to the student to demonstrate their theoretical, methodological and practical knowledge derived from the graduation profile of the degree program. The completion examination has considered two components: a multiple-choice component built on reagents that derive from the minimum knowledge matrix that the degree program has developed for this purpose, and another component of practical application. The knowledge matrix has been organized based on the graduation profile, its associated learning, thematic axes and contents, as well as the weighting guidelines for the examination grade. The completion exam has been designed so that it can be solved by the graduate in a minimum of two hours and a maximum of four hours. The completion exam has been given by the student through the mechanisms defined by each degree course. In the event that a student failed the exam, he or she has had the opportunity to take a completion test [7].

Another option of qualification for the graduates was the work of degree, by means of which the student had to demonstrate the integral handling of the knowledge acquired throughout his professional formation. Table 1 summarizes the work options

Table 1. Degree work options by area of knowledge.

Area of knowledge	Degree work option
All areas	Research projects
	Essays or academic articles
Social Sciences and Human Behavior Area	Ethnographies
	Systematization of experiences
	Communicative products
	Research and/or intervention practices
Education Area	Case analysis
	Methodological proposals
Science and Technology Area	Technological proposals
	Technological devices
	Technical projects
	Experimental works
Life Sciences Area	Experimental works
Administration and Economics Area	Case analysis
	Business models
	Entrepreneurship

of the degree program for each area of knowledge [7, 8]. Of these options, each degree program chose a maximum of two options in addition to the completion exam [7].

3 Result Analysis of Implementation of SDU

The Politécnica Salesiana University was created in 1994. At the date of constitution of the SDU, it kept records of the following data: enrollment, graduates, and undergraduates.

Based on the historical information of the UPS, the number of undergraduate candidates to graduate through the Special Degree Unit nationwide was 772, of which 32 correspond to Cuenca, 673 to Quito, and 67 to Guayaquil. Table 2 shows the numbers and percentage of graduates corresponding to each faculty nationwide. It can be seen that the largest number of students is concentrated in the Social Communication Faculty.

Table 2. Distribution of candidates to enter the SDU per faculty nationwide.

Faculty	Amount	Percentage
Social Communication	133	17,23
System Engineering	107	13,86
Pedagogy	91	11,79
Accounting and Auditing	89	11,53
Business Administration	77	9,97
Electronic Engineering	53	6,87
Psychology	43	5,57
Intercultural Bilingual Education	40	5,18
Mechanical Engineering	35	4,53
Management and Leadership	22	2,85
Management for Sustainable Local Development	20	2,59
Electric Engineering	11	1,42
Applied Anthropology	9	1,17
Biotechnology Engineering of Natural Resources	9	1,17
Environmental Engineering	9	1,17
Pastoral Theology	7	0,91
Philosophy and Pedagogy	6	0,78
Physical Education	4	0,52
Agricultural Engineering	3	0,39
Labor Psychology	2	0,26
Industrial Engineering	1	0,13
Civil Engineering	1	0,13
Total	772	100,00

3.1 Analysis of Results Nationwide

Out of 772 candidates to opt for the Special Degree Unit, 616 managed to obtain their degrees under this mode; conversely, 156 did not.

3.2 Analysis of Results per Headquarters

Out of 616 students who managed to graduate under the Special Degree Unit, 20 correspond to Cuenca's Headquarters, 555 to Quito's Headquarters and 41 to Guayaquil's Headquarters. The relationship between graduate and undergraduate students per headquarters is shown on Table 3.

Table 3. Graduate and undergraduate students at SDU per headquarters.

Headquarters	Graduates	Undergraduates	Non graduate
Cuenca	32	20	12
Quito	673	555	118
Guayaquil	67	41	26

3.3 Analysis of Results by Faculties Nationwide

The results of the number of graduates per faculty nationwide who have graduated through the Special Degree Unit, as well as those who did not, are summarized in Table 4. It can be seen that faculties like Physical Education, Philosophy and Pedagogy,

Table 4. Graduate and undergraduate at SDU per Faculty nationwide

Faculty	Graduate	Undergraduate	Non graduate
Physical Education	4	4	0
Philosophy and Pedagogy	6	6	0
Agricultural Engineering	3	3	0
Civil Engineering	1	1	0
Biotechnology Engineering of Natural Resources	9	9	0
Industrial Engineering	1	1	0
Management and Leadership	22	21	1
Social Communication	133	121	12
Applied Anthropology	9	8	1
Pastoral Theology	7	6	1
Intercultural Bilingual Education	40	34	6
Pedagogy	91	74	17
Management for Sustainable Local Development	20	16	4
Psychology	43	34	9
Business Administration	77	60	17
Electronic Engineering	53	41	12
System Engineering	107	79	28
Accounting and Auditing	89	63	26
Environmental Engineering	9	6	3
Electric Engineering	11	7	4
Mechanical Engineering	35	21	14
Labor Psychology	2	1	1

Agricultural Engineering, Civil Engineering, Biotechnology Engineering of Natural Resources and Industrial Engineering managed to graduate all their students who entered the Special Degree Unit.

3.4 Analysis of Results per Faculties on each Headquarters

Being aware that all faculties have implemented the Special Degree Unit in every headquarters and after taking into account all specific characteristics, the number of graduates and undergraduates has been verified. Such results are summarized in Table 5.

Table 5. Graduates and undergraduates through the Special Degree Unit per Faculty in all headquarters

Faculty	Cuenca		Quito		Guayaquil		Total
	Graduates	Undergraduates	Graduates	Undergraduates	Graduates	Undergraduates	
Business Administration	-	-	57	17	3	0	77
Applied Anthropology	-	-	8	1	-	-	9
Social Communication	4	2	117	10	-	-	133
Accounting and Auditing	3	1	45	18	15	7	89
Physical Education	4	0	-	-	-	-	4
Intercultural Bilingual Education	-	-	34	6	-	-	40
Philosophy and Pedagogy	-	-	6	0	-	-	6
Management and Leadership	-	-	21	1	-	-	22
Management for Sustainable Local Development	-	-	16	4	-	-	20
Agricultural Engineering	-	-	3	0	-	-	3
Environmental Engineering	1	0	5	3	-	-	9
Civil Engineering	-	-	1	0	-	-	1
System Engineering	0	1	63	17	16	10	107
Electric Engineering	-	-	7	3	0	1	11
Electronic Engineering	3	0	32	4	6	8	53
Biotechnology Engineering of Natural Resources	-	-	9	0	-	-	9
Industrial Engineering	-	-	-	-	1	0	1
Mechanical Engineering	0	1	21	13	-	-	35
Pedagogy	4	6	70	11	-	-	91
Psychology	-	-	34	9	-	-	43
Labor Psychology	1	1	-	-	-	-	2
Pastoral Theology	-	-	6	1	-	-	7

3.5 Análisis de los resultados referentes a la opción de titulación escogida por los estudiantes

An analysis of the options to graduate students has been carried out in order to identify the tools that have contributed in a greater extent to their graduation. These results are shown in Table 6. 44,81% of students finishing their studies that entered the Special Degree Unit who have decided to take the completion exam; however, it is needed to consider that a student could have failed the examination in the first instance. In this regard, more than half of the students chose a second chance completion exam. The amount and percentage of students who approve the exam in the first and second instance are shown in Table 7; 55,19% of students have chosen options to graduate

Table 6. Options to graduate chosen by graduate students

Options to graduate	Amount	Percentage
Completion exam	276	44,81
Technical project	104	16,88
Case analysis	84	13,64
Academic article	56	9,09
Research and/or intervention practice	34	5,52
Communicative product	32	5,19
Experimental work	9	1,46
Systematization of experiences	8	1,30
Essay	4	0,65
Research project	4	0,65
Methodological proposal	2	0,32
Degree work	2	0,32
Ethnography	1	0,16
Total	616	100,00

Table 7. Students who approved the comprehensive exam and the grace comprehensive exam

	Students	Completion exam	Second chance completion exam
Amount	276	127	149
Percentage	100%	46,01%	53,99%

different to the comprehensive exam. The percentage is composed in this way: 16,88% chose the Academic Project, 13,64% chose the Case Analysis, 9,09% chose the Academic Article, the rest of the options to graduate are represented by percentages inferior to 6%.

4 Conclusions

At a national level, 772 students finishing their studies that could have recourse to the Special Degree Unit, 87% of the students suitable to have recourse to the Special Degree Unit belonged to the campus in Quito, 9% of the campus in Guayaquil, and 4% in the headquarters in Cuenca. At a national level, the largest group of students finishing their studies that could join the Special Degree Unit was from the major of Communications representing 17,23%, followed by System Engineering with 13,86%, Pedagogy Major with 11,79%, and Accounting and Auditing with 11,53%, the rest of majors have a percentage inferior to 10%. Out of the total number of students finishing their studies that were suitable to have recourse to the Special Degree Unit 616 students graduated, which represents an 80% (effective rate at a national level). Out of the 156 students who did not graduate under the Special Degree Unit, 75% belongs to the campus in Quito, 7% belongs to the campus in Guayaquil, and 8% belongs to the headquarters in Cuenca. The major of Communications, which had the biggest number of students at a national level in the Special Degree Unit, graduated reached 90, 98% of students, the mayor of System Engineering reached 73,83%, the Pedagogy major with 81,32%, and the major of Accounting and Auditing with 70,79%. Out of the total number of students who entered the Special Unit of Graduation and graduated, 44,81% chose the option of the Comprehensive Exam, equivalent to 276 students, out of these, 46.01% approved the exam in the first instance while 53,99% appealed for the Grace Comprehensive Exam. After the comprehensive exam, the options to graduate that mostly contributed to students' graduation were the Academic Project with 16,88%, Case Analysis with 13,64%, Academic Article with 9,09%, and the other options to graduate represent percentages inferior to 6%.

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Curriculum Design Based on Agile Methodologies

Rodolfo Bojorque(✉) and Fernando Pesántez

Universidad Politécnica Salesiana, Cuenca, Ecuador
{rbojorque, fpesantez}@ups.edu.ec

Abstract. This work demonstrates how the curricular design processes at a graduate level, that is to say the one aimed to the academic offer leading to a third level professional degree, are positively affected when adapting and implementing agile methodologies that are generally applied to software product design process. This represents a considerable reduction of time and the sequential effectiveness of the process. The study considers 712 undergraduate programs from 30 higher education institutions in Ecuador that, based on the applicable legislation, had to re-design their entire academic offer within a set period. As a fundamental contribution, the methodological model of agile curricular design adopted by the Politécnica Salesiana University from Ecuador is described, whose results show that 96% of their careers achieved this goal in the established period, higher than the average effectiveness rate of other Higher Educations Institutions, which was 69.85%.

Keywords: Agile methodologies · Curricular design · SCRUM

1 Introduction

The continuous and fast evolution of ICTs promotes social changes never seen before in all aspects of society; this includes education. Our society requires relevant study programs that respond to the same speed of change; the university satisfy these requirements in the curriculum. However, the curriculum design process according to [1] must be designed in a flexible and dynamic way so that through an "emerging curriculum", each apprentice or group at any time is allowed to raise new proposals for content, problems, and information based on their interests and purposes. This situation demands the inclusion of new methodologies for curricular designing to maintain the rhythm that society requires in its evolution and to guarantee the sequential assurance throughout the different levels of curricular concretion.

Excluding education, there are certain areas of knowledge that while aiming to solve the reality of continuous and fast changes have incorporated methodologies that allow them to go hand in hand with new social challenges. That is the case of computer science that has dabbled into the implementation of agile methodologies to optimize time and resources for the design of software products for such exercise cannot be conceived today as the creation of a product that responds to the logic of traditional project planning. Likewise, the theory of complexity explains all these new interactions between elements of a system that requires to be conceived as such in a specific environment.

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In section two of this article, a review of agile methodologies and complexity is carried out as an approach to its applicability in education. Section three details the proposed methodology and explains the different adaptations of agile methodologies to the curricular design. Section four presents the results obtained in the curricular design process of 712 degree-level undergraduate programs in Ecuador, of which 43 adopted the proposed methodology. Finally, section five provides conclusions and recommendations.

2 Review

2.1 Agile Methodologies

According to [2], agile methodologies arise as the need to make software products tangible, generally the creation of a product is linked to the execution of a project; however, the results and evidence of the product can only be observed in the final stage of the project, which generates dissatisfaction and questions in the clients who want to appreciate prototypes or preliminary versions during the development of the project instead of receiving reports or documentation.

The first approach of agile methodologies consisted in changing the traditional vision of project management, according to [3] a project is a temporary effort that is carried out to create a product, service or unique result. The temporary nature of the projects implies that a project has a defined beginning and end. The end is reached when the objectives of the project are achieved or when the need that gave rise to it no longer exists. Likewise, a project can be terminated if the client (client, sponsor or leader) wishes to terminate it. Being temporary does not necessarily mean that the duration of the project must be short. It refers to the commitments of the project and its longevity. In general, this quality of temporality does not apply to the product, service or result created by the project; most of the projects are undertaken to create a lasting result.

It is evident that the concept of the PMI manifests a linear vision of the execution of a project, the agile methodologies give a turn to this vision by incorporating the following premises: a great problem can be broken into smaller problems, it is possible to focus on what is really important and forget about the rest, it can be assured that a product or work will be always delivered. It is feasible to seek feedback, if it is necessary, a course must be changed, it increases the logic of being responsible [2].

Subsequently, recognized critics in the area of software development created and published the agile manifesto that provides general guidelines on this new alternative methodology to traditional methodologies. This generated agile development community that were formalizing their own agile methodologies, among the most recognized we can mention Extreme Programming [4] and SCRUM. For our study we adopted the SCRUM methodology since it incorporates a generalist and unbiased vision to the field of software product development, according to [5] it defines itself as an agile methodology of adaptation, iterative, rapid, flexible and effective, designed to offer a significant value, quickly throughout the project. The methodology is structured in such a way that it is compatible with the products and the development of services in all types of industries and in any type of project, regardless of its complexity.

The framework of the SCRUM methodology is divided into six principles: Control of the empirical process, self-organization, collaboration, value-based prioritization, time boxing and iterative development, which constitute the core of the SCRUM framework and are mandatory in all projects. It is considered that five aspects must be addressed and managed throughout the project: organization, business justification, quality, change and risk. Finally, there are nineteen processes that address the activities and the specific flow of a SCRUM project. Table 1 provides a comparison between the most relevant aspects of traditional project management versus the execution of SCRUM.

It is relevant to mention that in SCRUM method, the iterative processes are managed through the sprints, a sprint refers to an activity execution that must be obtained as a result of a deliverable, in this way a project consists of several sprints that always deliver a product in that way it is not necessary to wait until the final stage of the project to have the results.

2.2 Complexity

It arises from the inherent interdependence between the different elements of a whole, in this case of knowledge. This interdependence can affect one of its parts or the whole [6]. In that regard, [7] adds that complexity is the information that a system lacks in order to fully describe and understand its environment. However, in today's society, what often happens is that complexity is an excess of information product and/or interactions, therefore, it is necessary to carry out a "selective connection of elements" to reduce levels of complexity [8]. Consequently, education should promote general intelligence by referencing the complex, the context, in a multidimensional way with a global conception [9].

With this vision of complexity, it is highlighted by [10] in which it is remarked the emergence of knowmad society as a global change product, driven by the accelerated technological and social development, globalization and the thrust of more creative and innovative contexts typical of complexity, however there is a paradoxical coexistence between the paradigms of society 1.0 related to a society based on industry and agriculture that ran from the eighteenth to the twentieth century; a 2.0 society based on the knowledge society that materialized in the twentieth century and society 3.0 characterized by the knowmad workers that appear in this twenty-first century. Table 2 is a comparison between the paradigms of society 1.0, 2.0 and society 3.0.

In this context [8] poses the following questions: why are we educating? Are we educating to create factory workers and bureaucrats? Or do we educate to create innovators, able to take advantage of their imagination and creativity? It is clear that the company needs all these profiles but does education really offer us the opportunity to develop the third question?

In this way, Ecuador had the political will to incorporate the paradigm of complexity in higher education throughout the country, and by law, the universities should re-design their academic offer, the work of [11] was considered as the guide to define a higher education curriculum from the systemic complexity, establishing the parameters that allow to visualize the complexity existing between science and technology with the different social, political and economic actors, according to [11] the objective of a university career responds to an interaction dynamics between the epistemology of

Table 1. SCRUM versus the traditional project management taken from [5].

Aspect	SCRUM	Traditional project management
The emphasis is on	People	Processes
Documentation	Only minimum, as required	Exhaustive
Process Style	Iterative	Linear
Upfront planning	Low	High
Prioritization of requirements	Based on business value and regularly updated	Fixed in the project plan
Quality assurance	Customer centric	Process centric
Organization	Self- Organized	Managed
Management style	Decentralized	Centralized
Change	Updates to Productized Product Backlog	Formal change management system
Leadership	Collaborative, Servant Leadership	Command and control
Performance measurement	Business value	Plan conformity
Return on investment	Early/throughout project life	End of project life
Customer participation	High throughout the project	Varies depending on the project lifecycle

Table 2. Domains of society 1.0, 2.0 and 3.0. Taken from [10].

Domain	1.0	2.0	3.0
Fundamental relationships	Simple	Complex	Complex –creative
Conceptualization of hierarchical order		Heterarchical	Intentional (self organizationn)
Parts relationships	Mechanics	Holographic	Sinergestic
World view	Deterministic	Indeterminated	Being designed
Causality	Lineal	Mutual	Not casual
Change process	Mounting	Morphogenic	Creative destruction
Reality	Objective	Perspective	Contextual
Place	Local	Globalization	Globalized

science, the profession contexts of action and the subjects that students and professors learn, since multi- diversity of approaches and dynamics presented, it is necessary to go from linearity and uniqueness with the subject in study is made with the dynamic objectual systems and the networking with the objective to inform about the complexity of knowledge and professional reality.

According to [12], the different curricular design schemes have their concretion in the macro- and meso-curricular levels, under this perspective we can classify the fundamental elements of the curriculum from the systemic complexity in: pertinence and object of study, as structure of the macro curriculum, the profile of graduation, practice and research model according to the meso-curriculum; and the descriptors of the subjects constitutes the micro curriculum.

3 Methodology

To detail the methodology, it is important to identify the fundamental elements of the curriculum, as mentioned in Sect. 2, the definition of the curriculum is defined at the macro, meso and micro-curricular levels composed of the following elements.

3.1 Relevance

The relevance is the complex interrelation between the public interests manifested in [13], the market interests that reflect in the productive and industrial sector, the sources of employment generation and the prospective analysis of the science. This trilogy ensures a relevant academic offer with a national planning, in that way any academic offer can ensure specific labor sectors, being these public or private ones for future professionals and additionally enhance the possibilities of own generation of employment in favor of the productive model planned by the State. This study is also an instrument of social development, planning and public policy since it allows us to demonstrate it, in the first order, its own strategy that emerges from the correct understanding of the surrounding reality and, above all, from the categorization and prioritization of the collective problems of society [14].

3.2 Object of Study

The systematic complexity gives relevance to all the multi, inter and trans disciplinary interactions of science, the object of study allows the visualization of different inter-relationships between knowledge and wisdom as stated in [11].

The tendency to fragment the object of study into dichotomous dyads that separate the profession knowledge, the education subjects of the different contexts, the wisdom science, among others, have planned a type of less dynamic analysis, which, due to its inflexibility is separated from the complexity of reality that has to be understood and transformed with the action and professional intervention models. The object of the major responds to an interaction dynamic among the epistemology, the contexts of professional action, and the subjects who learn, so, because of the multi-diversity of approaches and dynamics that they represent, it is necessary to pass from the linearity and uniqueness, which are the builders of the object, to a networked dynamic object system that gives an account of the complexity of knowledge and the professional reality.

For these reasons, the object of study is something concrete, complex, and dynamic that nucleated into science agglutinates, not only itself with the environment and its study realities, but also the subjects immerse in it, provoking changes in its own essence called science as well as in its inter-actors denominated context and subject.

3.3 Outcome Profile

The purpose of school cannot end up in teaching and learning the disciplinary contents established in the curriculum and organized into textbooks. The mission of the school is to impulse the development of skills, competences, and fundamental human qualities, which are required by the contemporary citizen to live in a satisfactory way in the complex contexts of the information times [1].

For [11] the outcome profile is the result of education trajectories that are woven into the learning dynamics. For this reason, its declaratory must include the being, the knowledge, and the knowing how to do something. Each level of curricular organization will evidence the learning approaches that the student will have to acquire at the end of the formative education process, in the same way that each formative area has to clearly express the education results that pursues.

The outcome profile is projected in time, because it is planned to get a different society from the actual one; if the contrary happens, the education will be subject to a social reproduction system, or it will support the status quo itself. However, in order to pursue the global education interests, we have to be agents of society transformation and no the spectators, so the outcome profile be always defiant.

3.4 Practice Models

It is considered an atrocity the divorce between theory and practice. In this sense [1] says that it is necessary to practice the theory, and to theorize the practice because the finality of knowledge is manifested in it, and it consists on the development of skills or practical thinking as substantial finality of education. The curriculum strongly exposes the referenced premise, when all the teaching components, first sign of the teaching-learning processes, is always complemented with experimentation practices and gets stronger with the autonomous work of each student.

3.5 Investigation Model

The investigation processes have to be evidenced in the curriculum; in this sense, the investigation at degree level, according to [15] will consist of and exploratory and descriptive level in education innovation and investigation contexts. Hence, it will promote the inclusion of students into research groups and education innovation groups (GIE), where learning is the subject that participates in networks of actors capable of stimulating the dialogue of knowledge to promote the construction of innovative solutions for problems related to their professional spectrum. Each university needs to know its context and to discover the most appropriate strategy to start walking, alongside, with its university community. It is the action of getting closer, of sharing, the ones that arouses innovation and discovers the field of investigation or research [16].

3.6 Subject Descriptors

An important part of the curriculum design in the third level of concretion consists on elaborating the micro-curricular descriptors. This situation allows to express the interdisciplinarity, and the systematic complexity of all the mentioned above in the execution units known as subjects.

The biggest problem of curriculum design has been fragmented into six smaller problems. Each one is a specific sprint of the methodology where the execution time of each one is about two weeks for its development. Therefore, the methodology has as minimum length 12 partial working weeks of the SCRUM team, which is adjusted to the professors' reality, and whose main activity is teaching, and cannot exclusively dedicate their time to the process of curriculum designing.

The six principles of SCRUM are kept, and five aspects of SCRUM regarding the macro, meso, and micro curricular development are adapted according to Table 3 for 45 majors at Politécnica Salesiana University of Ecuador (UPS).

Table 3. SCRUM aspects adapted to the methodology.

SCRUM aspect	UPS adaptation
Organization.-The central roles of SCRUM are Product Owner as the highest responsible for reaching the highest business values, SCRUM Master as the facilitator that assures that the group is equipped with a proper environment, SCRUM team is the group of people responsible for understanding the requirements specified by the product owner	Product Owner.-It was designated the Directors of the area of knowledge, who are responsible for the academic-scientific action of the teaching staff assigned to its area. SCRUM Master.- Academic Chief manages the different resources that the commissions require; in turn, the commission is the responsible for the process of curriculum redesign SCRUM Team.- the UPS Professors who have both professional and academic expertise are defined as a commission of curriculum design consisting of 5 experts per each university major
Business Justification. – it is based on the concept of deliver driven by the value. One of the key characteristics of any project is the uncertainty of the results, SCRUM tries starting the delivery of results as soon as possible in the project	The UPS academic projects are divided into the following deliverables: Pertinence Object of study Graduation Profile Practises model Research model Micro-curricular descriptors
Quality. - it is defined as the capacity of the product or the deliverables to meet the criteria of acceptance and reach the business value the customer expects under a focus of continuous improvement	Each deliverable is analyzed by the owner of the product along with the SCRUM Master. They are the ones who can accept the deliverable or require changes, improvements or adaptations. They take into account, as technical references, the current legal regulations, the curricular model proposed by CES and the institutional educational model
Change. - The SCRUM projects receive the changes through the use of the shorts and repetitive sprints that incorporate feedback from the customer in each sprint delivery	When projects are sent to CES for revision, observations before endorsement are usually received. Every time there are observations, the SCRUM Team is notified so that the corresponding changes can be executed

(*continued*)

Table 3. (*continued*)

SCRUM aspect	UPS adaptation
Risk. - It is defined as an unforeseeable event or group of unforeseeable events which can affect the objectives of a project and can contribute to its success or failure	The risks that are identified are considered surmountable issues and they are: Constant changes of the current regulations Dependency on third parties such as suppliers, experts, companies and industry, in special to define infrastructures of support to teaching practice

The deliverables detailed in Table 3 constitute the various sprints of the project. This is the most significant contribution of the methodology since after finalizing each sprint, there is a new element of the curricular project, which revitalizes the work of the groups and allows having a more efficient quality control on the part of the SCRUM master, task executed by the Teaching Vice-presidency.

4 Results

Results are presented based on the queries done on the database of the National Information System of Higher Education (SNIESE) https://infoeducacionsuperior.gob.ec/#/oferta-academica, where one can see the entire academic offer of the country's grade level. The UPS University as a Higher Education Institution has headquarters in the cities of Quito, Guayaquil, and Cuenca. For this case study, universities whose area of influence according to [13] is the same have been considered. The results announced by the SNIESE of the universities are valid since by law all schools had to redesign their academic offer in the same conditions of time and regulations. Not to execute the process of restructuring means that the university cannot offer the majors in question, hence the importance of the inclusion of responsive methodologies in the task of curricular design.

In Fig. 1, the proportion of the re-designed offer and the offer without redesign can be seen; the UPS University is the one that has almost all of its offer in re-designed projects. The identification of each university responds to the codification of Table 4.

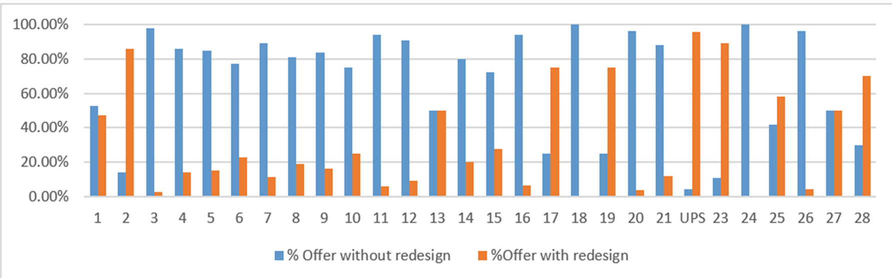

Fig. 1. Percentage of offer without re-design versus re-designed offer.

Table 4. SCRUM aspects adapted to the methodology

Code	University	Code	University
1	ESCUELA POLITECNICA NACIONAL	15	UNIVERSIDAD DEL AZUAY
2	ESCUELA SUPERIOR POLITECNICA DEL LITORAL	16	UNIVERSIDAD DEL PACIFICO ESCUELA DE NEGOCIOS
3	PONTIFICIA UNIVERSIDAD CATOLICA DEL ECUADOR	17	UNIVERSIDAD IBEROAMERICANA DEL ECUADOR
4	UNIVERSIDAD AGRARIA DEL ECUADOR	18	UNIVERSIDAD INTERNACIONAL DEL ECUADOR
5	UNIVERSIDAD CASA GRANDE	19	UNIVERSIDAD LAICA VICENTE ROCAFUERTE DE GUAYAQUIL
6	UNIVERSIDAD CATOLICA DE CUENCA	20	UNIVERSIDAD METROPOLITANA
7	UNIVERSIDAD CATOLICA DE SANTIAGO DE GUAYAQUIL	21	UNIVERSIDAD PARTICULAR INTERNACIONAL SEK
8	UNIVERSIDAD CENTRAL DEL ECUADOR	UPS	UNIVERSIDAD POLITECNICA SALESIANA
9	UNIVERSIDAD DE CUENCA	23	UNIVERSIDAD SAN FRANCISCO DE QUITO
10	UNIVERSIDAD DE ESPECIALIDADES TURISTICAS	24	UNIVERSIDAD TECNOLOGICA ECOTEC
11	UNIVERSIDAD DE GUAYAQUIL	25	UNIVERSIDAD TECNOLOGICA EMPRESARIAL DE GUAYAQUIL
12	UNIVERSIDAD DE LAS AMERICAS	26	UNIVERSIDAD TECNOLOGICA EQUINOCCIAL
13	UNIVERSIDAD DE LAS FUERZAS ARMADAS (ESPE)	27	UNIVERSIDAD TECNOLOGICA INDOAMERICA
14	UNIVERSIDAD DE LOS HEMISFERIOS	28	UNIVERSIDAD TECNOLOGICA ISRAEL

Likewise, in Fig. 2, the number of majors is categorized by universities, in this case, the UPS is among the five universities of the country that more majors offer, a situation that leads to consider the majors of the university as an acceptable sample for the statistical analysis:

It is important to mention that under the third transitory of the Regulation of the Academic Regime (Council of Higher Education, 2013), all universities had to redesign their academic offer of the grade level until December 4, 2016. The SNIESE consultation was made on January 13, 2016.

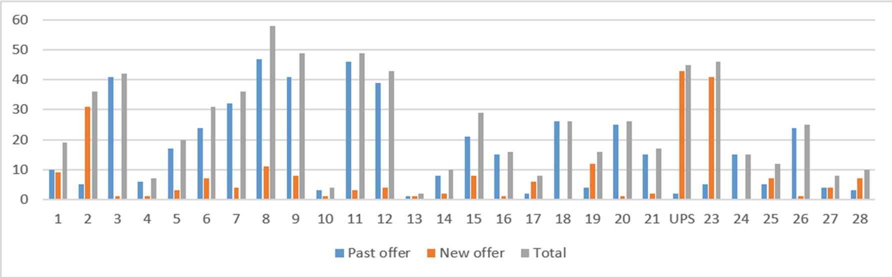

Fig. 2. Amount of majors offered by each university.

5 Conclusions

The curricular design is traditionally a process of academic reflection that cannot be understood as an educational response to market needs. It is necessary to incorporate variables of analysis that account for real relevance where besides the market, public policy has to be considered. A public policy which, in general terms, seeks to protect the collective well-being of society, another essential factor is scientific prospective, since the curriculum that is designed is not for today's professionals but the professionals of the next four or five years.

The vision of a curricular design from the systemic complexity has by default the demand of a considerable amount of time. Facing this problem the planned methodological proposal provides a timely solution that allows developing curricula in small spaces of time, compiling and adapting the work that is It carries out the development of software products to respond to the vertiginous change of the information and knowledge society

The SCRUM methodology for curricular design allowed the redesigning teams to reconcile the daily university functions with this process. Regarding efficiency, the productivity of the professors was increased without requiring additional hours, the master SCRUM, the institutional manager of the process, obtains products at the end of the sprints of each SCRUM team, allowing quality management of the process during the execution of the same one.

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Managing Design and Ergonomics at the Macro Level – The Design Policies

Rita Assoreira Almendra(✉)

Faculdade de Arquitetura, CIAUD, Universidade de Lisboa, Lisboa, Portugal
almendra@fa.ulisboa.pt

Abstract. This paper brings an overview of a part of a proposed Course of Managing Design and Ergonomics (from macro to micro levels that we assume to be a desirable elective course to the Design Doctoral Program at the Faculty of the author, from the University of the author. Thus, the paper will explore specifically the approach to be done to the management of Design and Ergonomics within it at the Macro level. The knowledge on these issues allows students to have a broader perspective on its management, one that includes the design (and within it ergonomics) participation and impact in terms of national and global strategies. Until know the academic approach to these issues is done by Design Management and ergonomics management as separated issues that are strictly focused on the business level and sometimes it expands themselves to the project management (what is known as "operational level" at the business design management stage). With the proposed approach to the curricular unit we hope to enrich students' perception and knowledge about design and ergonomics influence in the world and the way it can be planned, monitored and evaluated at distinct stages of its intervention. The main reasons behind the choice of this topic are: (a) the fact that the contents to be taught in this context normally are not disseminated in Design Education; (b) the circumstance that this is a PhD course in which broader approaches and understandings are necessary to support better framing and critical perspectives about the Design discipline its relationship with ergonomics and its intervention in the world.

Keywords: Design management · Managing design and ergonomics
Design education

1 Introduction

This is a short approach to the management of Design (including ergonomics) at the Macro level presenting the concept itself and the way it can be useful to students especially the ones at the PhD level. The knowledge on the issues integrating the macro scale of managing design and ergonomics allows students to have a broader perspective on managing Design, one that includes the design (and within it ergonomics) participation and impact in terms of national and global strategies. Among the aims of the course there is one of making PhD students aware and knowledgeable about the broadness and nature of design impacts in the world being ergonomics one of the key issues to pay attention to. During the course, there are going to be unfold the main subtopics

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considered to be determinant at this level of design's intervention. By doing so we intend to give students the possibility of identifying the key elements of this territory of action including the agents, strategies and methodologies that make part of this system in which design is both an agent of change and subject of the change.

1.1 Course Context

In general terms, we propose to exist three intertwined approaches that structure the knowledge in this specific area: (a) Design (including ergonomics) as a strategic tool at national levels and its management at a global point of view; (b) Design and ergonomics at the business level and (c) Design and ergonomics at the process/project level.

Managing Design (including ergonomics) at the macro level is a specific lesson designed to be taught in the 5th week of the course's calendar. It follows lessons related with the acquaintance with key concepts of management and design management as well as with an overview on the relationship design and ergonomics management have with specific issues such as information and knowledge management or innovation management. Thus, it is important to understand the structuring of the course that is here represented by the diagram on Fig. 1. If students do not have any previous contact with any of the three areas its processes and context of interventions, they should familiarize themselves with them not only as separated topics per se but mostly in its interrelationship thus being able to have an ample and trustful vision of the socio-political-economical context of design nowadays. The proposal of this course takes place in a context where in one hand, we acknowledge the increasing complexity of the design process and a progressive shortening of the time to complete it. In another hand, there is a paradigm change in economic development of developed and underdevelopment countries which become dependent on the production of innovative products and services with higher added value. Furthermore, social and cultural issues experienced an increase of importance in the last 20 years and the so called social design as well as the sustainable design are assumed by western governments as central topic on their agendas. Therefore, the main objective of this course is to enable students to better understand, reflect upon and operate in this complex context and to develop research with an ampler and accurate perspective of Design and ergonomics intervention in the world's innovation.

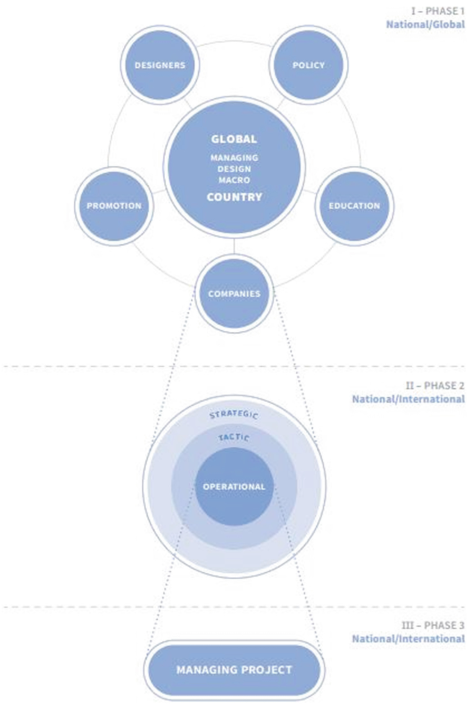

Fig. 1. Diagram of the managing design course with its phases

2 Managing Design (and Ergonomics Within It) at the Macro Level

The structuring of the complete lesson is twofold including both a theoretical and a practical approach to the contents. This didactic option is related with the necessity of making knowledge more 'visible' to students since they can use the theory and apply it. This is done using exercises that are not focused on this paper.

2.1 Theoretical Approach

The theoretical approach will confront students with knowledge about the concept of managing design and its relationship with ergonomics as a key aspect of the design thinking and process at the macro level and the importance it has at the PhD education level. The main topics to be addressed are: design policies, its management and the contribution the topic can have to PhD research (the topic addressed in this paper); Design world rankings (DWR) and its relationship with design policies; structuring elements of DWR; DWR potential contributions to PhD research; Global and National Studies on design and ergonomics' macro contributions.

2.2 Practical Work

The practical work aims to give students the chance to operationalize the knowledge taught; there is an exercise to be developed in group. In general terms, the practical work has a component to be develop in class and another one to be done outside classes. Regarding the work to be done in class it has do to with the structuring of the tasks to be done; the selection of supporting bibliography and case studies as well as the critical discussion of the contents to be developed. This work will be supported by several tools (prepared matrix and forms to help collection and structuring of information) to be provided by the teacher to students.

3 Managing Design (MD) at the Macro Level - What Is Meant by MD at the Macro Level

Managing Design at the Macro level refers to the management of Design assumption and use (real and potential) and the role ergonomics has in it in the wide context here represented by regions, nations and the world. It has to do with acknowledging the contribution of Design (taking into account the key contribution of ergonomics) to the nations and world's shaping, its role as a player, a facilitator or even an engine of societies' transformation and development. The Design Leadership Board, an organism created in 2011 at the European level that aims to boost design use at European level, defined a set of cultural, social and economic values (see Fig. 2) that should support design intervention at this level that we believe to be better implemented if the key role of ergonomics is to be carefully and fully assumed.

Fig. 2. Design system is based on cultural social and economic values [1]

In a closer look to each of the value dimensions we clarify the role of design in cultural terms as one that should celebrate diversity and identity; that should tap into continuity of culture and heritage, that should promote synergy through complementarity; furthermore and in what concerns design vision and actions these must consider social equity as an enabler of a sustainable and inclusive growth pursuing the achievement of higher life quality - Here ergonomics are an essential element while contributing to the quality of life; Finally design actions must be resource responsible, effective, efficient and accountable revealing a true commitment with ethics professionalism.

4 The Importance of Acknowledging MD at This Level in the PhD Education

The importance of design policies knowledge and its framing derives from the awareness that such knowhow enables students at different formation levels to understand the role of design and within it of ergonomics at a macro-global level. Moreover, to understand the world design rankings and the way they are structured gives the designers and the ergonomists and design researchers the ability to situate the discipline´s intervention in societies. Learning who, why, when and how regions, countries and global structures manage design is of key importance to PhD students in Design independently of their research theme and focus. For those that have topics not so close to this area of knowledge it allows a more thorough understanding of the net of connections and interrelationship design establishes in the economic, social, technological, legal, political and cultural dimensions of societies; on the other hand, for those who have closer approaches to this area of knowledge it allows them to have a more grounded and informed background on the historical and contemporary actions of design and ergonomics at this level. Furthermore, to study these issues makes all designers more aware of the ethical importance of design and ergonomics intervention in the world. It gives them a broader perspective of design implications in world's modeling thru a comprehensive decoding of the macrolevel structures that rule societies.

5 Design Policies (DP) as a Managing Design Topic

5.1 What Is a Design Policy

Has Patrocínio [2] acknowledges there are authors using the terms 'design policy', 'design promotion', and 'design promotion policy' as equivalents [3]. However, he defends the idea proposed by Bourn [3] that design promotion refers to an 'action', while design policy relates to a 'principle of action' what implies that design promotion integrates design policy.

If we look at the Cambridge dictionary a policy is "a set of ideas, or a plan of what to do in particular situations, that has been agreed officially by a group of people, a business organization, a government, or a political party" [4]. Moreover, if we seek a definition on a business specialized dictionary such as business [5] dictionary the terms come together with procedures (pointing to the direct connection the concept has with actions) and the definition is: "A set of policies are principles, rules, and guidelines formulated or adopted by an organization to reach its long-term goals and typically published in a booklet or other form that is widely accessible. Policies and procedures are designed to influence and determine all major decisions and actions, and all activities take place within the boundaries set by them. Procedures are the specific methods employed to express policies in action in day-to-day operations of the organization.

Together, policies and procedures ensure that a point of view held by the governing body of an organization is translated into steps that result in an outcome compatible with that view."

Important to attain from both definitions is the idea of formalized plan meaning that some activities are designed to occur in an interval of time. Additionally, and coming from the business definition of policy we clarify the specific need of having actions to be taken that imply major decisions to be taken in a limited and well-defined territory. However, some elements are missing on these two definitions: the fact that policies have a strategic nature; and the specific reference to the stakeholders involved and the fact that they have explicit and shared responsibilities in designing and implementing those policies.

There is still a stricter definition such as the one proposed by Bourn [3] that defines a policy as "the translation of government's political priorities and principles into programs and courses of action to deliver desired changes." Bourn [3] designed a circular model for policy-making that integrates three phases starting with design, followed by implementation and finishing in maintenance that are operationalized in four key steps from planning to assessment (see Fig. 3).

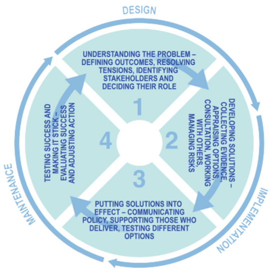

Fig. 3. Bourn model for policy making [2]

In the case of Design policies, one can also mention the generic definition of Gisele Raulik-Murphy [6] that proposes design policies to be understood as strategies defining the vision and directions adopted by a country in terms of its understanding and use of design. Moreover, it is important to present the DeEP definition of Policy since this organism is the one responsible for monitoring the European existing policies. In their view: "Policies are the way in which a Political System shares a set of rules, activities, and processes necessary for the transformation of existing conditions into preferred ones." [7], and "Design policies aim at sharing a set of rules, activities, and processes to support design through the reinforcement of design capabilities at all levels of the policy cycle (The policy cycle is a conceptual model describing the stages involved in making policy and its cyclical, iterative nature. There are many variations in the number and types of activities within the cycle – for DeEP the used stages are: 1 – agenda setting; 2 – policy formation; 3 – policy adoption; 4 – policy implementation; 5 – policy evaluation" [8].

This definition introduces another key concept related with design policies which is the design capabilities that are strictly linked to the organization's level of design management. In this case, they give respect to the "capabilities set needed to carry out design activities. Capabilities are recognized in three macro areas as it can be seen in Fig. 4.

(a) Design Leadership, (holistic view, how people give meaning to things) is encountered when design participates to the strategic choices of the firm/organization, so that a design-driven innovation strategy is the core activity carried out through a people centered approach being ergonomics a key issue;
(b) Design Management, (visualizing/materializing, managing the process) is the ability of managing design resources, in terms of human resources, design process (and ergonomics within it) and creativity, economic resources;
(c) Design Execution (applying new technologies) involves the presence of human resources with technical skills, design and ergonomics technologies and infrastructures, investments in the NPD process [8].

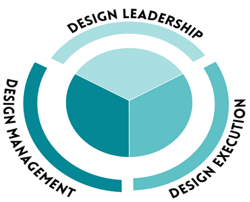

Fig. 4. Design capabilities [9]

Each of these is divided in one or more specific skill to detail the focus of the area. In a closer look to design policies' literature it is impossible not to notice its intimate link to innovation policies and there is a strong desire in Europe to assess the impact of such policies by the creation of frameworks and indicators to evaluate all actions – from macro scale (regional, national, European) to micro (specific initiative) - thus allowing a comprehensible picture of its impacts. That close connection can be observed in the creation of The European Design Leadership Board (established in 2011) that has issued a set of recommendations on how to enhance the role of design in the innovation policy in Europe at the national, regional or local level trying to promote a joint vision. Taking a broad-based view of design, they identified 21 policy recommendations grouped in six areas for strategic design action as it can be seen in Fig. 5 [1].

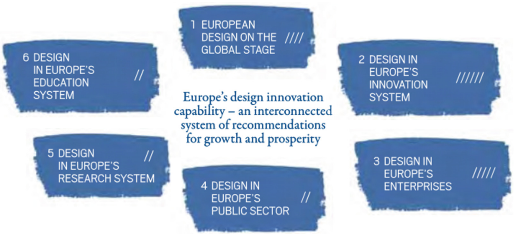

Fig. 5. Recommendation for growth and prosperity through design intervention [1]

Important to notice in the diagram of Fig. 5 the broadness of areas and stakeholders involved in the process. The development and implementation of a design policy thus implies the coordinated and articulated intervention of the government – normally through the ministries of industry and/or economy) of the public and private agents dedicated to the promotion, execution, regulation, normalization and support of industry and technology namely in the sectors of production and education. In general, the use of design (and ergonomics within it) at the national/global levels is accomplished because it exists the vision shared by all part involved in the process that it is a creative and innovative process able to generate sustainable and efficient solutions to specific problems, which have a key importance not only to the production, technological and economic areas but also to the social, environmental and cultural fields. The vastness of the design policy study includes the possibility of learning how countries establish their goals considering factors such as: research and education, design and ergonomics as professions; companies and industries; public sector, general population and international public. This is also the view of Gisele Raulik Murphy that has written her PhD Thesis with the title "A Comparative Analysis of Strategies for Design Promotion in Different National Contexts" in 2010 [3] in which she concludes that:

- The competitiveness has been the main rationale for design policies being intimately linked with economic goals and visions;
- There are different agents involved in design policies such as: initiatives by individuals – introduce design to small communities; government programs – foment the use of design by industries; official public policies – foster the use of design resources.
- Supporting design by itself is not being enough to have companies using it; It is necessary to combine it with design promotion, to support it with design education and to align it with other government policies;
- Recent trend on design policies to be more user centered and have an ethical approach rather than only benefiting economic development.

Due to its clear importance in nation's development it is than important to comprehend design policies in respect to its genesis, structuring elements, drivers and implementation modus allowing the students to relate it to different historical, cultural, political, technological, legal, social and economic contexts thus perceiving the positioning of design (and ergonomics as a key element) in each context and the influence it has in national/global strategies.

Figure 6 makes clear different stakeholders are involved in design policy design and implementation. The way they interact, their role in society and in the nation strategy differs from country to country depending on multiple factors such as culture, politics; legal framing, social structure etcetera. Finally, one must acknowledge the European effort of developing a meta structure of European design policies [10] which is called the European Design Innovation Ecosystem that is represented in Fig. 7.

Fig. 6. Design policy structuring elements [2]

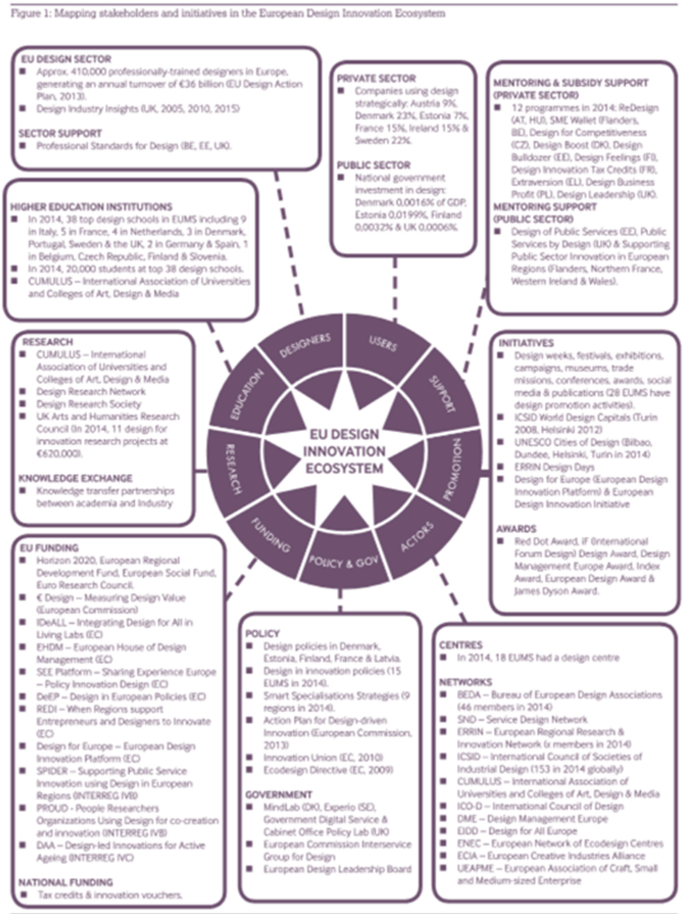

Fig. 7. Stakeholders and initiatives in European Design Innovation Ecosystem [10]

5.2 Types of Design Policies

Different contexts call for distinct approaches. This is also the case of design policies. Moreover, there are countries that had created formalized design policies (with and without reference of the key role ergonomics plays in it) and others that didn't do it although having design programs and actions that all together can be seen as a pre-design policy. That is the case of most European countries that try to implement design programs (some in a more explicit way other in a tacit one). This state of art implies the actual lack of evaluation that results in less effective design/innovation policies that must be studied not only in what concerns its nature but also regarding its national performance and its impact in firms. If one performs a diagnosis about design policies around the world it is identifiable that different countries generate different policies with distinct goals. In general, there are two approaches: one more economic oriented; another more wellbeing oriented, both requiring an ergonomic approach that is fundamental. There are countries (specially the more developed ones such has the Nordic) that use design as a booster of life quality; other countries make a stricter use of design policies focusing on industry development and performance (it is the case of BRIC countries in general). As stated in DeEP report [11] countries like the Netherlands have implanted design policy within industrial policy hence there are a limited number of particular design policies; Belgium displays embryonic but growing design initiatives although the impact of such initiatives remains to be determined; Some smaller countries like Malta and Cyprus, have little or no policies related to design nevertheless they have good design-related businesses; Sweden and Denmark enjoy high levels of trade, exchange of design-related activities, personnel and resources further strengthening an already well-defined policy. Generically it is observable in all design policies the existence of design programs aiming at the increase of national companies and industry and services competitiveness however the role of ergonomics its far from being well defined. Such focus excels from the set of developed countries as well as from other countries that have a precise need to boost its national competitiveness A closer look to the work developed by Raulik Murphy and Cawood [7, 12–14] allow us to understand the diversity of policies and ways of engagement among stakeholders that are best acknowledged using visual diagrams such as the ones presented in Figs. 8, and 9 for example.

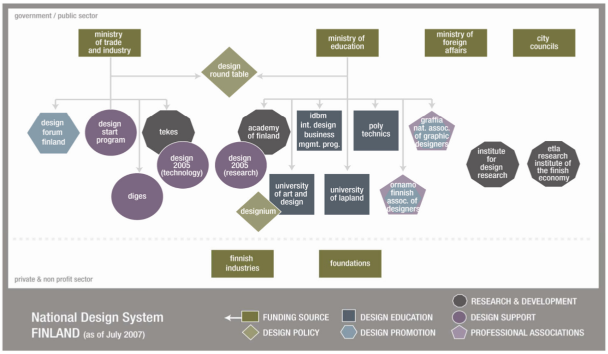

Fig. 8. National Design System Finland [14]

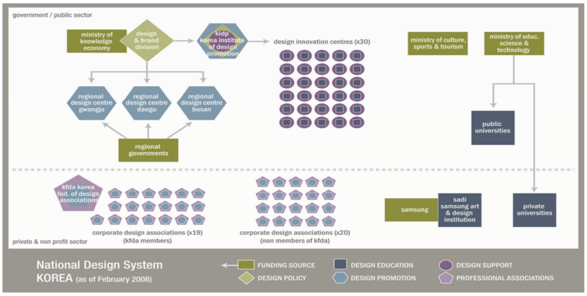

Fig. 9. National Design System Korea [14]

The analysis of the different country diagrams designed by Raulik Murphy and Cawood [14] shows as the most relevant fact the distinct role of the government in comparison to the non-profit/private sectors in the chosen four countries. As seen in Figs. 8 and 9 the governments in Finland and Korea play a key role by defining strategies and financing design policy and programs. Otherwise in Brazil and India (which diagrams we didn't present here) it is visible the absence of public funds being design programs mainly independent self-guided initiatives. As a direct consequence, there is a difference with more private/non-governmental initiatives seen in India and Brazil compared to Korea and Finland. Additionally, leadership and integration are clearly more defined in Korea and Finland in comparison to the developing countries, which may be a result of the key financial role played by their national governments. Regarding the way different design policies perform it is also central to refer the design policy monitor 2015, a publication dedicated to review innovation and design policies in Europe since Europe seeks a convergence of European countries policies to have a competitive benefit of a joint action. In this document, some trends in Europe to be developed until 2020 are anticipated such as: Policy-makers across Europe will integrate design more holistically within innovation policies as well as smart specialization strategies and some will develop design action plans. Governments will seek to build design and ergonomic capabilities with small and medium-sized enterprises by integrating design and ergonomics as an eligible cost within innovation programs such as mentoring, subsidy, tax credit and export schemes as well as developing dedicated design support programs. Governments will develop their internal capacities for design-driven innovation by training staff in design and ergonomics methods, employing design managers and establishing multi-disciplinary innovation units. Public sector administrators will recognize design (and ergonomics within it) as an enabler of innovation in multiple policy domains such health, social, environmental, digital and transport policy and as a method for inclusive policy-making. Besides the study of Design Policies (DP) the study of Design World Rankings (DWR) is a very relevant element along with other governmental and nongovernmental studies about this macro presence and use of design. Unfortunately, we have no space to develop the topic that integrates this approach to managing design at the macro level.

6 Conclusions

This paper stresses the importance of Managing Design at a macro level stressing that the key role of ergonomics usually is absent from this approach and presents design policies as one of the topics that can help students to understand this level of design and ergonomics intervention. The main conclusion of the study of these issues (design policies, design world rankings and other macro studies on design performance and use) is that having a holistic view on how design (and ergonomics within it) affects and is affected at the macro level benefits student's understanding of the broadness and deepness of design and ergonomics intervention in societies. A second immediate conclusion one must be aware of is that the vastness of issues raised with this singular topic calls for the study of numerous subjects ranging from economics to education. Thus, it is essential to promote a lesson (following one in which these issues are presented to students) in which case studies are offered to make evident some of the aspects taught and explained.

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A Physically Immersive Platform for Training Emergency Responders and Law Enforcement Officers

Gordon Carlson and Nicholas Caporusso(✉)

Fort Hays State University, 600 Park Street, Hays, USA
{gscarlson,n_caporusso}@fhsu.edu

Abstract. Training law enforcement officers and emergency responders requires significant investment in terms of time, financial resources, logistics, organization, and personnel reallocation.

In this paper, we introduce a physically immersive platform based on Virtual Reality for training enforcement and emergency personnel, and for evaluating physical and psychological stress. The proposed system is co-designed with end users to maximize the performance and outcome of training.

Moreover, the platform includes features for accelerating the development of innovative technologies, equipment, and user interfaces, by integrating the knowledge and experience of law enforcement officers and emergency responders into virtual/augmented reality design simulations.

Keywords: Physical immersion · Motion tracking · Training
Law enforcement · Emergency responders

1 Introduction

Training is a crucial and recurring activity for Law Enforcement Officers (LEOs) and Emergency Responders (ERs). Every year, depending on the agency and territory, they must accomplish a required minimum number of hours of training [1] for specific competences (e.g., use of force, conflict resolution), scenarios (e.g., active shooter, hazardous materials contamination), procedures (e.g., cardiopulmonary resuscitation), and equipment (e.g., lethal firearms, non-lethal Tasers). Higher ranking officers are often required to train on coordinating the intervention of multiple teams across varied departments (e.g., tactical emergency medical services) in more complex situations, such as first response or command and control [2]. An important benefit of this training is improved officer behavior in police-citizen encounters [3], a significant aspect of preventing violence escalation [4].

Among the most common forms of training are realistic simulations, which usually occur in physical spaces such as abandoned buildings or "disaster cities" where the environment is designed to match the purpose of the simulation. As this is a very expensive activity that poses logistical challenges, larger agencies and metropolitan departments have necessary financial resources and can leverage existing facilities or team up

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to share simulation environments. Unfortunately, the majority of departments operate in sparse communities or rural areas with limited personnel. Consequently, training results in a difficult compromise between complying with required standards, optimizing the use of available funds, and allocating human resources without disrupting necessary public safety activities. This is especially true for other types of safety workers like natural resources officers (NROs) who are deployed in rural areas and might receive less training than police [5]. When training does occur, it often takes place in classrooms where poor student engagement and lack of opportunity for simulation can lead to failure in the field.

In recent years, virtual reality (VR) simulations have been introduced to offer convenient, affordable, and reusable training programs. However, they lack physically engaging experiences and introduce habituation to what is perceived as nothing more than a video game. Moreover, VR removes most psychological and nearly all physical stress, which are crucial aspects of training. It usually supports a limited number of users at one time preventing much needed experience working in teams and with multiple stakeholders. Indeed, LEOs and ERs report that physical interaction in the environment, the presence of other people, and the risk of being shot with simunitions are key factors to delivering a realistic experience by eliciting the same cognitive and physiological reactions produced in the field.

In this paper, we introduce a novel immersive platform for providing LEOs and ERs with realistic training thanks to the incorporation of physiological and psychological dimensions.

2 Related Work

[6] reviewed several systems for VR-based training for disaster preparedness and response and reports some prominent uses of in the United States' Department of Homeland Security (DHS), Centers for Disease Control and Prevention, National Institutes of Health, National Science Foundation, and other organizations relevant to the present work including police departments (PD), the Office of Emergency Management (OEM), and the Federal Emergency Management Agency (FEMA). The potential benefits of VR-based training for mitigating the effects of post-traumatic stress disorder (PTSD) are discussed in [7], which presented examples of how re-experiencing the trauma in a simulated environment can integrate and improve traditional therapy. Also, immersive reality has been utilized to predict behavior and symptoms of PTSD [8].

Being able to collaborate with other team members is an important theme in training public safety officers. [9] documents an instructional environment for team intervention and cooperation in situations that involve multi-agency coordination. In this regard, cave automatic virtual environments (CAVE) have been utilized for training purposes [10–12] in the last decade. Several studies demonstrated their effectiveness as a tool for providing users with more immersive safety simulations. Nevertheless, CAVE-based simulations suffer from high infrastructure development and maintenance costs, lack of trained technicians, limitations in terms of mobility, and concerns related to logistics. Consequently, they are usually implemented in central locations and utilized by departments that can allocate resources for this type of training. Their cost prevents them from being installed in rural areas and they are not suitable for the disassembly and reassembly necessary for frequent transport.

The system discussed in [13] introduces a mixed-reality approach to providing first responders with full-scale safety training. The system is designed to support emergency response organizations and multi-agency cooperation; however, there is no information about development status. Conversely, several research projects [14, 15] focused on the use of low-latency motion tracking systems in combination with head-mounted displays (HMDs) to deliver highly immersive training experiences. The authors of [16] present a system based on augmented virtuality for training law enforcement officers in deescalating situations. Although several focused on the use of head-mounted displays and see-through lenses, the main issue remains limited movement in space, often compensated for with the presence of treadmills or sophisticated platforms for motion detection.

Nevertheless, most systems lack the crucial physical dimension necessary for eliciting psychological and physiological responses. Thanks to recent advances in motion capture technology, zero-latency cameras enable physically immersive virtual reality (PIVR) environments in which users can freely move through physical space as part of the simulation. The authors of [17] present a PIVR system that uses a 25 m^2 physical space for creating a simulation that delivers the experience of a 300 m^2 space where multiple players can interact with virtual and physical objects.

3 System Design

The proposed system consists of a modular hardware/software platform designed for providing LEOs, ERs, and public safety personnel with a physically immersive environment for training and testing purposes. The hardware component is an infrastructure-based motion-tracking system that captures the location and movement of users in physical space and converts them into virtual characters in the simulated environment, which players visualize using a head-mounted display. This, in turn, provides real-time rendering of a simulation scenario that maps the physical world into the virtual space and vice versa, enabling users to interact with digital objects and players, which can be either completely simulated or a virtual representation of a physical entity.

The system was co-designed with expert trainers from Police Departments, Sheriff's Offices, and other public safety organizations from a rural county with in a part of the United States with a relatively small population. Moreover, the system incorporates a situated cognition model (see Fig. 1) in which scenario scaffolding enables building different simulations and different versions of the same situation to provide users with the opportunity of acquiring knowledge embedded in the specific virtual representation. For instance, the dynamics of a specific scenario (e.g., hostage situation, active shooter, fire) can be combined with a host of physical locations (e.g., office building, school, restaurant). As a result, law enforcement officers and public safety personnel can run the simulation multiple times and experience different locations, dynamics, tactics, levels of threat, and outcomes. The system is designed to be *modular* and *extensible*. New items such as equipment, weapons, furniture, and interactive objects (collectively referred to as dynamic physical elements, or DPEs, because they can all be manipulated in real time during simulations), physical or digital, can be added to the simulation by designing their virtual model and by tracking their physical counterpart. Specifically, users can interact with other players and experience the simulation knowing that there are real humans physically present in the environment. As a result, they can interact with one another and experience interpersonal dynamics that conventional VR and AR environments do not incorporate. Furthermore, the proposed system leverages physical immersion and embodied cognition to improve the performance of training: being able to deliver the same type of psychological and physical experience that occurs in a real-life scenario could be beneficial for (1) eliciting unexpected reactions (e.g., loss of visual acuity, excessive force) and identifying their root cause; (2) providing support, coaching, and additional training; and (3) repeated exposure to a scenario reducing anxiety associated with uncertainty and fear.

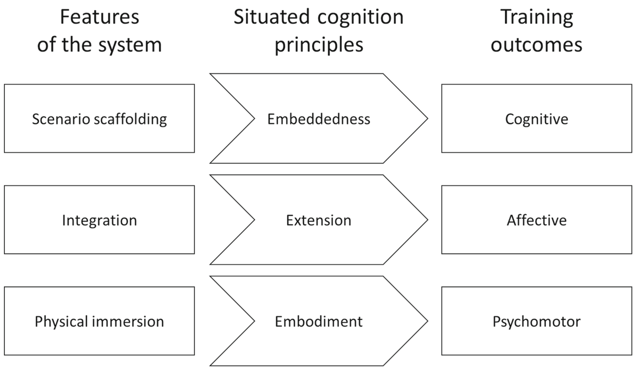

Fig. 1. The situated cognition model of the system, adapted from [18, 19].

3.1 Architecture Design

The design of the proposed system follows a modular approach and its architecture consists of two main sub-systems: the hardware and software components (Fig. 2).

This allows for designing and testing user interfaces for a wide range of public safety environments. This, in turn, enables construction of missions and scenarios involving multiple LEOs/ERs while iteratively generating variations necessary to maintain engagement and test how users' reactions change from a physical and cognitive standpoint. The architecture also allows for potentially automating the generation of adaptive scenarios based on participant response or training goals by making use of narratively driven scripts or even AI/fuzzy logic engines.

Removing cross-communication between the manager units reduces complexity, production time, and costs. More importantly, each component is interchangeable and can therefore be developed and improved independently. Thus, the platform can be disseminated widely in an open format serving researchers and practitioners by encouraging collaborative use and avoiding the pitfalls of walled or siloed systems.

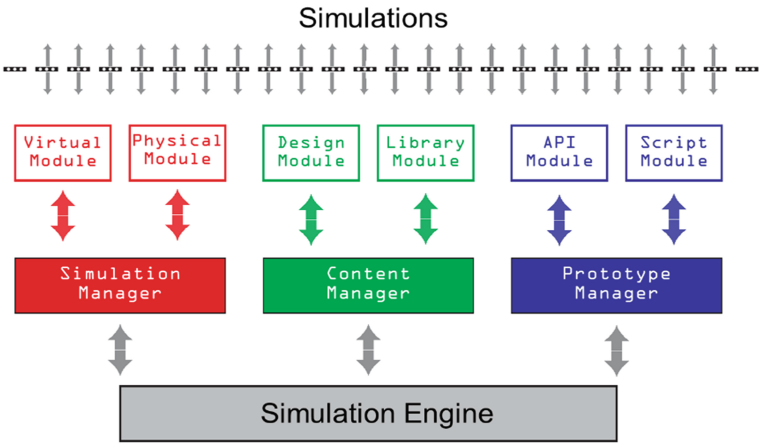

Fig. 2. The architecture of the system.

3.2 Hardware System

The hardware component of the system consists of three main elements: (1) an infrastructure for high-speed motion-tracking; (2) a wearable set of devices; and (3) physical equipment, items, and props (elements of the scenario).

The infrastructure for motion capture is based on state-of-the-art, low-latency cameras that can detect, track, and integrate into a rendered virtual/augmented reality experience relevant people, equipment, and objects, in real time. The infrastructure can integrate from a minimum of 6 up to 24 off-the-shelf zero-latency cameras that acquire and process images within milliseconds to minimize lag and to improve the responsiveness of the action-feedback loop. The platform is designed to be modular and scalable: it supports physical spaces ranging in area from 30 to 3000 square feet and need not be rectangular. Depending on the requirements of the scenario, the infrastructure can detect and track up to 40 individuals and objects (e.g., simunition weapons, furniture, and environmental items like vehicles and physical obstructions) and seamlessly integrate different DPEs in the virtual environment by using their interactive 3d model as a digital counterpart. After acquisition, the infrastructure transmits the video streams to a central node, the simulation server, where images from individual cameras are processed: relevant data points are extracted from markers and converted into position and orientation coordinates of individual elements.

The wearable component consists of a set of personal devices, including a head-mounted display and a lightweight, non-intrusive backpack that hosts a high-performance laptop computer that communicates with the simulation server and renders the environment on the HMD. The personal set includes reflective markers that are attached to specific areas of the body to enable tracking the position, orientation, and movement of users while they navigate the simulated environment.

As a third component, the physical model includes all the equipment utilized in the simulation. Several scenarios might not require any additional DPEs, as they might involve tracking users only. Other simulations might involve the use of simunitions, the presence of physical elements (e.g., fire extinguisher) and equipment (e.g., resuscitation kit) which are necessary to accomplishing the simulation. By using appropriate markers, DPEs can be tracked and added to the VR scene, so that users can interact with them. The possibility of integrating an arbitrary number of different types of physical items extends the possible applications of the system beyond training purposes. As a result, the proposed system can be utilized for evaluating how different types of weapons change the reaction of the users and the outcome of the mission. Additionally, it can be utilized for analyzing the impact of different configurations of physical elements on the performance of personnel during their operations. Low-cost material can be utilized to produce physical replicas of the actual equipment: items will appear as they are rendered in the simulation, thus, their actual appearance is less relevant. Consequently, a set of molds can be utilized for producing low-cost, actionable pieces of equipment such as simunition weapons, active items (e.g., fire extinguisher, door lock), or passive elements (e.g., doors, bricks, debris). Only mechanical parts and joints that can be manipulated in the simulation (e.g., triggers, push buttons, and handles) will be required to have higher realism. In addition, the platform includes a plugin system of hardware appliances that control environmental conditions (e.g., fans, heaters, fog machines) that can be operated by technicians or controlled by the simulation server.

The hardware component of the proposed system has several advantages. It supports up to 40 individuals and items, which makes it suitable for training of multi-team interventions over very large simulation environments. The system also enables tracking elements over an area of 50 by 50 feet of physical space, which can be expanded to a virtual space of an order of magnitude. Moreover, it allows integration of environmental conditions (e.g., smoke, heat) and terrain (e.g., mud, snow, and gravel) providing trainees realistic experiences interacting with the eccentricities of the environment itself. Consequently, it integrates the benefits of traditional realistic simulations and the advantages offered by VR in terms of affordability, reuse, and resource optimization.

Although the physical module of the system incorporates an infrastructure, it is designed to be easily disassembled and to fit in a standard NATO pallet (47.24 × 39.37 in.) so that it can be transported and shared across neighborhoods, counties, or even states at little cost. Also, it can be assembled in a relatively short time and calibrated by a non-expert using a predefined routine. The entire system can be shipped to a new location and provide training to an entire department for the same cost as sending a single trainee to a traditional training facility. Potential return on investment for cash-strapped government agencies is enormous.

3.3 Virtual Module

The software module consists of a core piece of software that allows the main components of the system to communicate and share information in a timely fashion with data management capabilities.

The Simulation Manager executes the virtual and augmented reality experiences for research and training purposes through two modules: the Virtual Module, which processes the interactive scenarios for up to 12 participants in real time, and the Physical

Module which processes the haptic and tactile elements of the experience. The Simulation Manager includes:

- an immersive Virtual Reality engine (built on top of industry standard 3D engines such as Unity) for deploying scenarios based on the requirements of the simulation (i.e., type of scenario, number of officers involved, environment conditions, mission objectives);
- an easy-to-use editor for designing simulation scenarios, based on a library of 3D assets, or for automatically generating new scenarios or variations using previously-recorded data;
- a set of Application Programming Interfaces that support integration of third-party software plug-ins (e.g., for recording and analyzing simulation data) as well as technology and equipment (e.g., physiological sensors, LEOs' personal data terminals).

The Content Manager allows for the design and use of adaptive, customized research/training scenarios by leveraging two important design components. The Design Module allows non-technical persons to rapidly design scenarios for use in research and training, including virtual and physical elements, without advanced training or the need for full time professional operators. The Library Module is a repository of existing scenarios, simulation datasets, and user interface prototypes created by LEOs and ERs themselves. This takes advantage of the incredibly successful formats of social design ecosystems like Thingiverse, 3D Warehouse, maker collections, etc.

The Prototype Manager operationalizes testing and deployment of new user interface systems by providing software "hooks" for connecting hardware and software without the need for customized software. The API Module provides plug-and-play integration for commercial/retail equipment that currently exists (e.g., Oculus Rift, NVIDIA graphics, Unity3D/Unreal/Godot, haptic feedback hardware). Researchers and developers inventing new equipment can use the Script Module which provides a sort of "universal translator" between the system and non-standard hardware or software. This serves the acceleration of novel tools by circumventing time consuming and costly API development through direct access to the system.

4 Discussion

The system relies on commercially-available hardware components and, thus, the platform benefits from economies of scale: individual parts can be easily replaced if damaged and alternative implementations can be realized by substituting individual devices with other commercially-available options.

As pointed out by technical experts who contributed to designing the system, the core philosophy of any type of training is to experience a particular situation several times so that when they occur in real life, LEOs and ERs will be prepared to react to it as they already went through the same scenario and evaluated the potential options and their consequences. Therefore, one of the key features of the software system is the possibility of simulating a broad range of scenarios and adding variations that can generate experiences which are likely to occur on the job. Consequently, the proposed training platform could have real-world impact for improved training resulting in faster, accurate, and predictable performance from public safety personnel. For example, ERs in rural areas would normally have no opportunities for practicing an active shooter scenario and therefore would be ill-equipped to support a metropolitan agency if they were called in to support. Moreover, it is difficult and expensive to stimulate the physical and psychological aspects of dangerous or time-sensitive situations (such as fatigue, fear, temperature, limited visibility, etc.) which can be added to the system, studied, and even controlled by the simulation manager. In addition, data can be recorded for further analysis, for track-record purposes, and for use in new simulations.

One of the main characteristics of the system is its versatility both as a software simulation and in terms of hardware configuration. For instance, the physical simulation space can be adjusted to represent a tunnel requiring responders to navigate practical obstacles such as debris, platforms, tunnels, and cars. The virtual simulation space can impose environmental conditions such as low lighting, smoke/fog, and loud sounds. Up to 12 individuals can simultaneously participate in the simulation to test user interface designs that include geolocation and hazardous chemical detection systems while training LEOs and ERs on team-based tactics for emergency response. Furthermore, the system can be utilized as a test-bed for training initiatives involving coordination of larger groups comprised of responders from multiple agencies. Personnel from different teams can be physically located in the same testing area, but virtually separated by the simulation.

5 Conclusion

In this paper, we introduced a novel platform that addresses the needs for public safety personnel training, which includes the development of innovative user interfaces and technologies. To this end, we designed a physically immersive platform that integrates motion tracking technology and VR simulations to achieve realistic and convenient simulations. The proposed system was co-designed with law enforcement officers and emergency responders, and it integrates knowledge and experience of trainers into the design of VR- and AR- based simulations.

The proposed system addresses two crucial needs of police departments, emergency management agencies, and other organizations devoted to public safety: training and evaluation of new equipment. In regard to the former, the system operates as a VR-based platform that can be utilized to meet training requirements and accomplish additional on-demand training in a cost-effective fashion. Furthermore, the proposed system integrates the possibility of supporting the development and evaluation of new equipment like user interfaces and smart devices. By using simulated environments, public safety personnel, researchers, and industry experts can collaboratively develop new technologies and simultaneously evaluate their effectiveness in a single, seamless pipeline.

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Conceptual Description of the Key Determinants of Effective Monitoring and Evaluation System

Callistus Tengan[1,2(✉)], Clinton Aigbavboa[1], and Didi Thwala[1]

[1] Sustainable Human Settlement and Construction Research Centre, Faculty of Engineering, and the Built Environment, University of Johannesburg, Auckland Park, South Africa
callyclarke@gmail.com, didibhukut@gmail.com, caigbavboa@uj.ac.za

[2] Department Of Building Technology, Bolgatanga Polytechnic, Upper East Region, Sumbrungu, Ghana

Abstract. This chapter presents a conceptual description of the key determinants of effective monitoring and evaluation system as critical factors for the successful implementation of projects. This is done through a comprehensive review of literature. Nineteen (19) monitoring and evaluation determinants were identified via the extensive review of journal, conference and academic thesis'. The top five (5) determinants were identified as budgetary allocation for M&E, data quality, technical capacity of the M&E team or department, leadership and monitoring and evaluation information system (MEIS). The study advocates for a critical approach to budgeting and allocating funds for M&E, the quality of M&E data gives the necessary confidence in the M&E finding upon which project panning relies on, there is the need to build the technical capacity of the M&E team and or department through training to undertake effective M&E and finally adopt effective and efficient approach in the implementation of M&E. The compliment of all the above determinates will see a shift in the era of poor performance to one of a successful project implementation.

Keywords: Budgetary allocation · Data quality · Leadership
Monitoring & Evaluation · Stakeholder involvement

1 Introduction

The accepted objective of project management has been to achieve SUCCESS; thus, achieving quality, cost, and time [1]. Attaining this level of success, according to Munns and Bjeirmi [2] is hinged on factors such as a realistic goal, competition, client satisfaction, a definite goal, profitability, third parties, market availability, the implementation process, and the perceived value of the project. Also the relationship between project success factors, project performance and ultimately project success have been studied [3] which posits factors of success as meeting project time, budget, technical specifications, safety, profitability, user satisfaction, fitness of purpose, free from defects, value for money and within a pleasant environment and social obligation [3].

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Significant among factors to ensure that projects elements affect project performance positively to predict the level of success is M&E [4]. M&E is concerned with ensuring that planned activities, resources, project elements and components are coordinated effectively and efficiently as planned [5, 6]. These efforts will largely contribute to the successful completion of projects. Several studies have been conducted in diverse fields of study and practice to identify the factors that contribute to the success or failure of the implementation of monitoring and evaluation [6]. Hence the need to understand the key determinants that impacts the monitoring and evaluation of projects is imperative. This chapter looks at the highly ranked (*key*) factors that greatly influence the effective implementation of monitoring and evaluation. This is achieved through the review of literature on existing conceptual models of monitoring and evaluation frameworks and ranking same to ascertain the highly perceived determinants of effective M&E.

2 Methodology

A two-stage research approach was used. This involved the review literature to identify the M&E determinants and secondly the use of survey questionnaire. The extensive literature study identified nineteen (19) factors while the questionnaire survey helped to determine in ranking the key determinants of M&E. According to Alreck and Settle [7] and Girden and Kanacoff [8], the survey research design was employed to enable the generalisation of the findings. The data were gathered from Ghana, Nigeria and South Africa using a questionnaire administered by online google form via e-mail. The respondent's were generally construction industry professional in the respective countries. The list was generated from the database of the Journal of Construction Project Management and Innovation (JCPMI) which included reviewers, authors, and scientific committee member of the Journal. The list, therefore, was deemed as a representation of a community of researchers and practitioners who had substantial knowledge and understanding on Monitoring and evaluation. Subsequently, the Kaiser-Meyer-Olkin measure of sample adequacy was performed which achieved a high value of 0.760 suggesting the adequacy of the sample size. Respondents were requested to rate all 19 identified determining factors on a 5-point Likert scale, where 5 represents extremely influential, 4 very influential, 3 somewhat influential, 2 slightly influential and 1 not at all influential. The respondents were required to answer the questions according to their experience on projects they had been involved. Data collected were analysed descriptively via the International Business Machines Statistical Package for Social Sciences (IBM SPSS) version 24.

3 Data Analysis and Discussion

3.1 Respondents' Information

Table 1 present information on respondents on three categories. Their academic qualification, years of experience in the construction industry and professional association affiliation of respondents. This was to ensure that respondents had the requisite knowledge, understanding and expertise to proffer accurate response for the study. Table 1 indicates that about nineteen percent (19%) of respondents were PhD holders, sixty-seven percent master's holder and ten percent (10%) bachelor's degree in relevant construction education and related fields. Two percent (2%) each of respondents possessed higher national diploma (HND) and post-graduate diploma's (PGD) respectively. Majority of those surveyed, thus fifty-six percent (56%) had between six and ten years of construction industry experience. Less than nine percent (8.3%) had been engaged in construction industry practice for less than five years. Likewise, twenty-one respondents indicated that had more than a decade but less than fifteen years. Similarly, fifteen percent (15%) of the respondents had more than sixteen years of experience. Respondents showed membership to some recognised professional bodies within their respective countries and across the globe. Respondents from Ghana were mostly drawn from the Ghana Institute of surveyors and the Engineers (GhIS and GhIE), Ghana Institute of Architects (GIA) and the Ghana Institute of Construction (GIOC). From Nigeria, respondents belonged to the Nigerian Institute of Quantity Surveying (NIQS) and the Nigerian Institute of Estate Surveyors and Valuers (NIESV). Similarly, respondents from the South African Construction Industry were mostly members of the South African Council for Project Management Professional (SACPCMP). Some respondents indicated other professional associations like the Project Management Professional (PMP), the Chartered Institute of Builders (CIOB) and the Institute of Engineers and Technology (IET). The profile of respondents, therefore, assures the value and reliability of responses [9].

Table 1. Respondents' information

		Frequency	Percentage
Educational level	1 = Postgraduate (PhD)	9	18.8
	2 = Postgraduate (M-degree)	32	66.7
	3 = Degree (B-degree)	5	10.4
	4 = High National Diploma (HND)	1	2.1
	5 = Other	1	2.1
	Total	**48**	**100**
Professional body affiliation	1 = GhIS	13	27.1
	2 = GIA	5	10.4
	3 = GhIE	3	6.3
	4 = None/others	27	56.3
	Total	**48**	**100**
Years in construction industry	1 = ≤ 5 years	4	8.3
	2 = 6–10 years	27	56.3
	3 = 11–15 years	10	20.8
	4 = ≥ 16 years	7	14.6
	Total	**48**	**100**

4 Results and Discussion

4.1 Key Determinants of Monitoring and Evaluation

This section of the survey provided respondents with the opportunity to indicate the level of influence of determinants to the implementation of M&E on a five-point likert scale. From Table 2, budgetary allocation was ranked first having attain a mean score or 4.42 and a standard deviation score of 0.821. Data quality was ranked second (Mean = 4.35, Stad. Dev = 0.785), Technical capacity (Mean = 4.31, Stad. Dev = 0.748), Leadership (Mean = 4.29, Stad. Dev = 0.898) and monitoring and evaluation information system (MEIS) (Mean = 4.25, Stad. Dev = 0.812) were ranked third, fourth and fifth.

Table 2. Ranking of key monitoring and evaluation determinates

Determinants	N	Mean	Std. error	Std. deviation	Rank
Budgetary allocation	48	4.42	.118	.821	1st
Data quality	48	4.35	.113	.785	2nd
Technical capacity	48	4.31	.108	.748	3rd
Leadership	48	4.29	.130	.898	4th
M&E information systems	48	4.25	.117	.812	5th
Communication	48	4.23	.120	.831	6th
Stakeholder involvement	48	4.19	.125	.867	7th
Managerial skills	48	4.15	.123	.850	8th
Relationship between goals and output	48	4.15	.126	.875	9th
Appropriate M&E indicator	48	4.13	.118	.815	10th
Human resource capacity	48	4.06	.135	.932	11th
Stakeholder relationship	48	4.02	.128	.887	12th
Project organizational culture	48	4.02	.131	.911	13th
Approach to M&E	48	4.00	.130	.899	14th
Institutional framework	48	3.98	.125	.863	15th
Training	48	3.94	.147	1.019	16th
Beneficial community participation	48	3.67	.147	1.018	17th
Advocacy	48	3.48	.158	1.091	18th
Political influence	48	3.38	.173	1.196	19th

4.2 Budgetary Allocation for Monitoring and Evaluation

According to Kimani [10], budgeting is imperative to achieve effective monitoring and evaluation. Allocation of clear and adequate financial resource for effective M&E has become topical and imperative for the successful implementation of M&E [11, 12]. It is therefore not surprising that budgetary allocation was ranked the most significant among nineteen determinants of effective M&E. Similarly it has been argues by many studies that the successful implementation of M&E is firmly rooted in the provision of adequate financial resource [13–18]. It is, therefore, vital that in allocating sufficient funds for M&E, appropriate methods of budgeting are employed, the scope and complexity and activities involved in the project must be considered. Muiga [15] further posits that delineating M&E budget within the overall project budget position M&E the importance it deserves in project management. Timely release of M&E funds as and when it is required will safe any delays in M&E and ultimately promote the smooth running of the project. To guarantee that budgeting is done right and efficiently, the need for periodic auditing (internal/external) of M&E budget will ensure budget allocations is sustained and rightly so, influence effectively the monitoring and evaluation of projects. Quality of M&E is therefore guaranteed with adequate budgetary allocation [15]. Mugambi and Kanda [13] however cautioned that these allocation should be done in a controlled manner to eliminate any challenges in the implementation process.

4.3 Monitoring and Evaluation Data Quality

Most projects are faced with data quality challenges making it extremely difficult to take apt decision on project implementation. As postulate by Kusek and Rist [19], M&E should offer comprehensive and relevant data that will support decision making. Whiles monitoring and evaluation is concerned with the continuous gathering of project information [20–22] on activities regarding process and the utilization of project resources; materials, human and financial, the quality of the data on the project must be sufficient, reliable, accurate, valid and acceptable. Data collected should serve the purposes for which it was gathered. The quality of project data cannot be overemphasized for resource planning and interventions to prevent re-work therefore its importance in monitoring and evaluation. Mulandi [23] studying the performance of M&E systems in selected non-governmental organizations in Kenya argued that the quality of the M&E data was significant. In achieving data quality therefore requires automation of the M&E process and the utilization of information technology systems. Capacity development is also important to influence the quality of data collected.

4.4 Technical Capacity for Monitoring and Evaluation

Technical capacity (TC) of monitoring and evaluation team and department is key to the successful implementation of M&E. TC is the unique and practical knowledge possessed by the project monitoring and evaluation team. This capacity is evident in the ability of the M&E team to accomplish the set objective of the M&E in achieving project success. The strength of an organisation is associated with its human resource capacity [15] and as such without the requisite technical capacity, M&E team will fail in delivering the objectives of the M&E system in place [23]. Capacity development is essential to achieve, strengthen and maintain skills and capabilities for achieving developmental goals and objectives within specific time frame. Studies by [12, 14–17, 23–25] have all recognized the impact of technical skill on the role of M&E team and department towards the successful implementation of M&E.

4.5 Leadership for Monitoring and Evaluation

Leadership is notable a vital aspect of effective M&E [26]. It is the ability to influence, inspire and motivate other M&E team members to achieve defined objectives. It however does not always refer to a fixed position but rather it could be either formal or informal and at any level. Different parties (stakeholders) involved in projects exhibit different characteristics and interest and therefore the needs to have their interest managed and eliminate any power struggle and to ultimately guarantee project success requires strong leadership in the M&E process. Leadership is essential to ensure the successful coordination of the M&E process and activities to achieve accountability. Individual and team leadership capacities needs to be developed to improve the effectiveness and efficiency of M&E implementation. M&E leaders will ensure M&E systems are clearly developed with the right tools and techniques for implementation. According to Luthra and Dahiya [27] effective leadership is seen in how the leader communicate. Dissemination therefore of M&E finding to stakeholders underpins the success of the M&E process and hence the relevance of leadership. M&E leaders also requires appropriate leadership styles to make him effective.

4.6 Monitoring and Evaluation Information System (MEIS)

Information generation is very imperative for planning and decision making on project. Crawford and Bryce [28] recognizes effective Monitoring and Evaluation Information System (MEIS) to promote organisational learning, ensure project performance, demonstrate accountability. Using information technology in gathering, processing, and utilisation M&E data will ensure the quality of the data and give confidence to the finding and meaning generated from the data. M&E information is also preserved for future use in its original format while ensuring effective communication among M&E team members.

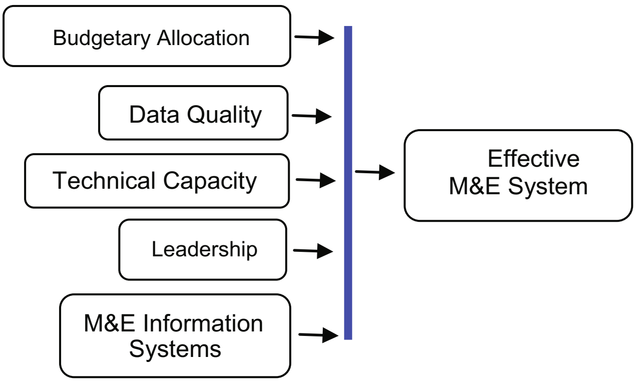

Fig. 1. Conceptual framework of key M&E determinates

5 Conclusion

This chapter sets to describe the key determinants of monitoring and evaluation. This was achieved via the review of literature and ranking the identified factors based on the perception of respondents. Nineteen (19) factors largely determined the effectiveness of M&E system. Subsequently ranking using the mean item score (MIS) revealed five (5) key determinates ranked from first (1st) to fifth (5th); budgetary allocation for M&E, M&E data quality, technical capacity of M&E team, leadership and the utilization of M&E information systems. A conceptual framework is hence developed (Fig. 1). The study suggests that financial and human resources are extremely important in the development and implementation of M&E systems. A robust M&E system will be evident to generate quality data for effective planning and accountability for decision making. Ultimately the success of the M&E process potentially will guarantee project success.

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Effectiveness of Enhancing Classroom by Using Augmented Reality Technology

Kunyanuth Kularbphettong[1(✉)], Pattarapan Roonrakwit[2], and Jaruwan Chutrtong[1]

[1] Science and Technology Faculty, Suan Sunandha Rajabhat University, Bangkok, Thailand
{kunyanuth.ku, jaruwan.ch}@ssru.ac.th

[2] Faculty of Information and Communication Technology, Silpakorn University, Bangkok, Thailand
ajpui20@gmail.com

Abstract. The use of augmented reality (AR) has become an opportunity to enhance teaching approach. AR is an amalgamation of multimedia information with 3D graphics, images, animations and sound to support the user's perception. The aim of this study is to design and evaluate classroom learning through AR technique for teaching science subject to secondary school students. The proposed study integrated AR learning application in an interactive learning environment. A quasi-experimental design of the pre-test and post-test for non-randomized control group was employed for this project and the participants consisted of students of secondary schools in Thailand. The results indicates that students were satisfied at the highest level by the learning activities and acquired the target knowledge as well.

Keywords: Augmented Reality · Blended learning · The efficient Students' achievements

1 Introduction

Science and technology are the significant issues to develop the country and improve the quality of life. Teaching and learning of Science subject is difficult to comprehend if there are limited of equipment and student do not practice by his/herself. With rapid development of science and technology, many countries foresee on the importance of science education to enhance the quality of life and standard of living by harvesting knowledge and education. Learning from additional media, it will help students to understand and have a good attitude towards science education.

Now Thailand is facing with an education crisis and needs to reform education by focus on critical thinking skills and the results of the Program for International Student Assessment (PISA) in 2015 showed that Thai children were ranked 55 [1]. The Ministry of Education is currently adjusting the curriculum based on the modern technology. STEM education helps to promote teaching Math and Science for children to insight in the contents.

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Augmented Reality (AR) technology is a popular technology applied in education and it can integrate the real world with the virtual world through devices. AR acts as the media to make it possible to study more details and simulate the environment to make it real. AR technology is an innovation for active learning to help in learning and teaching both students and teachers [2].

Also, there are much of research shown that augment reality applications based on mobile devices play an important role in learning and teaching nowadays [3, 4]. Therefore, this research aims to apply augment reality approach based blended learning to enhance learning ability of junior high school in science subject.

2 Related Works

The section shows an overview of the literature in augmented reality based on mobile application and blended learning to scope and define the theory and approaches adopted throughout this research.

The use of mobile technology acts as a tool to deliver electronic learning materials to both students and teachers with no longer barrier by space and time and mobile is integrated AR technology to enable users to have an experience within specific context. Augmented reality is defined as “the technologies that make the virtual objects to the real world [5]. Pokémon Go is a free-to-play, location-based augmented reality game created by Niantic and Nintendo that enabled players to find the Pokemon from a place in the real world and create communities [6]. According to Delianidi et al. [7], a mobile augmented reality (mAR) blended learning application was implemented to teach for primary school pupils and revised by exploiting the personalization techniques. Kaufmann [8] applied AR to remote collaboration by sharing a common virtual learning environment and virtual learning materials. Students participate to visualize and interact with lesson directly through “markers” to produce supplementary information to student rendered in a multimedia format. To improve feedback loop between students and lecturer, augmented reality techniques was applied to provide communication and interaction during lectures and the result was positive the perspective both students and lecturer [9]. Kularbphettong implemented AR application based on mobile to enhance learning of student in Physics subject and the student achievement was effective [10].

Blended learning is an innovation that combines modules, teaching and learning together through network to make learning more effective than listening to lectures in the classroom. Furthermore, it will focus on choosing the right media and the right learning objectives in various ways to increase the potential of teaching [11]. In addition, blended learning is the integration of face-to-face with online learning and support the accessibility, affordability, and ease of eLearning with the personalization, immediate feedback, and social interaction of traditional education [12]. A convergence of Augmented Reality (AR) with blended learning environment was used to learn for teaching English as a foreigner language [13]. AR-based blended learning was applied as scaffolding to better support blended learning strategies [14]. AR and blended was applied to teach the Marching Cubes algorithm and made students to understand and view through the camera [15]. Also, there are much of research analyzed these activities from the perspective of how AR was set in each activity to enhance learning and teaching.

3 Research Objectives

This section describes the objectives of this project and there were three primary objectives of this study:

– To develop a 3D augmented reality system on learning a science subject for junior high school.
– To evaluate the efficient of this application to meet the criteria of at least 80/80
– To compare Students' achievement between a control group and an experimental group.
– To study students' satisfaction of this AR application.

4 Research Methodologies

The purpose of this research was to develop AR mobile application and examine student perceptions regarding the use of an AR mobile system in learning a science subject for secondary science education. The research was a quasi-experimental research aimed at developing and finding the efficiency of this application to meet the criteria of effective education, with qualitative and quantitative research combined to develop this application, and enhance learning and teaching in a science subject.

Using a deductive approach. The sample of this study consisted of junior high school students in the second semester of academic year 2018. The process of designing amalgamated with blended learning consists of six steps as indicated below:

- The first step was to integrate teaching materials and review the related theories. This study focuses on studying student's behavior, learning objectives, content, tests, summaries and the environment.
- The second step was to identify learning activities in each unit from the curriculum and decide how to evaluate each learning activity.
- Assessment was prepared for the evaluation of the 3D modeling from experts.
- The pre and posttests were determined with the multiple-choice format.
- The application was implemented and samples were examined with the research materials.

Rapid application development (RAD) was used to develop the purposed application and RAD is the software development approach based on prototyping and iterative development [16, 17]. According to Martins [18, 19], RAD is divided in four distinct steps: requirements planning, user design, construction, and cutover steps as shown in Fig. 1. The first step of requirements planning is a preparation step to set goals and objectives, and the goal and purpose of the lesson is to set the target. User design is the step focusing on user interaction, where models and prototypes are built for supporting users. In the construction phase, application was implemented and the system was tested to see if it operated at an acceptable level. The cutover is the final phase including data con-version, testing, changeover to the new system, and user training.

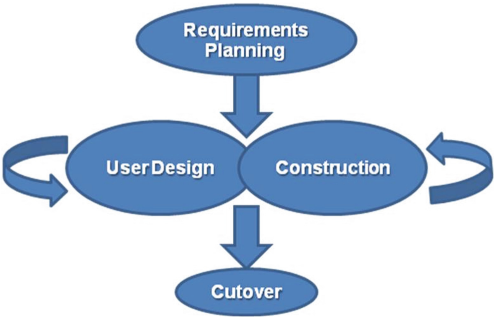

Fig. 1. Rapid application development (RAD) [18]

Figure 2 shows the system framework according to K.Kularbphettong and et al. There are four significant components including user profiling, searching, learning and testing modules. The user profile supports learners to register and edit his/her profile like personnel information, email address, username and password, and etc. students can search and learn content and knowledge about the science subjects in secondary school at level two. The contents of the learning part include 5 lessons and the presentation is a 3D augmented reality with voice and subtitles. After students had finished learning each lesson, they can take post exams and know results from the testing module of this application and the application provide post- tests and score results. This proposed application was assessed by 3 experts to verify the student's learning plan, content and the performance of this system. A 15-min pre-study presentation was conducted to introduce the students to the project. Students were asked to register personnel profiles on the application.

After the training session finished, the in-depth interviews were applied in the classroom and the samples were required to give the explanation and describe the learning situation. Data collection was conducted through a demographic survey, learning observations, and interviews. The data were analyzed by the statistical means, and standard deviation (S.D.). The level of the significance was p = 0.05 that formed the basis for or rejecting or not rejecting each of the hypotheses. To evaluate the effectiveness of learning material collected data from test and post-test was analyzed and measured by using E1/E2 effectiveness with 80/80 condition.

$$E_1 = \frac{\frac{\sum x}{N}}{A} \times 100 \tag{1}$$

$$E_2 = \frac{\frac{\sum F}{N}}{B} \times 100 \tag{2}$$

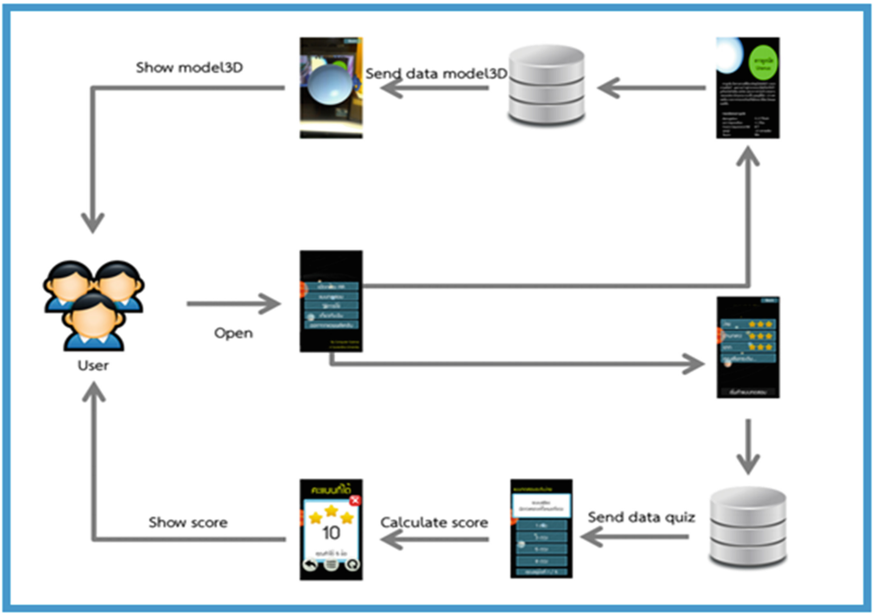

Fig. 2. The overview system of this system

When
E1 = the efficiency of the developed material
E2 = the efficiency of performance result
$\sum X$ = total score from lesson testing
$\sum F$ = total score from post-test
A = Total score of lesson testing
B = Total score of post-test
N = total number of students

Moreover, this research used questionnaires to test and evaluate the satisfaction of the student's learning in the programming language with games and a 5-point Likert scale was utilized to range from "strongly satisfaction" to "strongly dissatisfaction".

5 Empirical Study and Results

The purpose of this study was to examine students' learning achievements accomplished through the use of an augmented reality mobile in a science course. The results of this study are presented in three sections: evaluating the performance of the proposed application by experts; assessing students' learning achievements; and evaluating the satisfaction of the student's learning.

5.1 Evaluating the Performance of the Proposed Application by Experts

Black box testing and questionnaires were applied to test and evaluate the qualities of the system by three experts. Black Box testing was evaluated the error of the project as following: functional requirement test, Function test, Usability test, Performance test and Security test. The ability of this application was assessed by Functional Requirement test in needs of the users and Functional test was used to evaluate the accuracy of the system. Usability test was tested the suitability of the system. Performance test was used the processing speed of the system. Finally, Security test was evaluated the security of the system and Table 1.

Table 1. The results of he results of Black box testing

	Experts	
	$\bar{x}$	SD
1.Function requirement test	4.67	0.47
2. Functional test	4.69	0.47
3. Usability test	4.44	0.62
4. Performance test	4.49	0.50
5. Security test	4.40	0.65
Summary	4.53	0.54

The results were satisfactory, mean value for experts was 4.52, and standard deviation was 0.54 respectively.

5.2 Assessing Students' Learning Achievements

The comparative analysis of the learning outcome was conducted with 40 students learning with AR application and before starting test, students were took pretest to evaluate the knowledge of students. To analyze the progress of the student learning, the results showed that the students had 22.45 and 35.15 percent learning achievement before and after test, from the 40-point scale. The t-test value is 19.32 (Tables 2, 4 and 5).

Table 2. The results of assessing students' learning achievements

	Group	Score		E1/E2
		$\bar{x}$	S.D.	
Pre-test	40	22.45	1.50	81.62
Post-test	40	35.15	2.67	85.33

In addition, the performance of the proposed application, the efficiency of E1/E2 is 81.62/85.33, indicating that the game lessons effective 80/80 criteria.

Table 3. The results of assessing students' learning achievements

	$\bar{x}$	S.D.	Level
Teaching technique	4.63	0.48	Very high
The characteristic of the AR application	4.60	0.50	Very high
Teaching material	4.62	0.53	Very high
Quiz and evaluation	4.67	0.45	Very high
Total	4.63	0.49	Very High

Table 4. The results of the satisfaction of the student's learning in teaching technique

	$\bar{x}$	S.D.	Level
Teacher uses a variety of teaching methods appropriate to the subject matter	4.55	0.44	Very high
Teacher uses techniques to teach students to understand them more easily	4.72	0.48	Very high
Students have the opportunity to ask questions, express opinions, discuss, give advice and listen to their ideas	4.63	0.51	Very high
Teachers use language to teach that students can understand. It's easy and appropriate for content	4.65	0.47	Very high

Table 5. The results of the satisfaction of the student's learning in the characteristic of the AR application

	$\bar{x}$	S.D.	Level
Screen layout and design	4.42	0.49	High
Fonts, sizes and colors	4.72	0.50	Very high
Main menu easy to understand	4.65	0.51	Very high
Linking within the lesson	4.67	0.48	Very high

5.3 Evaluating the Satisfaction of the Student's Learning

The satisfaction of the student's learning was assessed by a questionnaire and the sample consisted of 40 students (number of boys = 26 and number of girls = 14). Data is presented in terms of descriptive statistics.

Table 3 shown the level of student satisfaction toward teaching and learning management and the overall is high (Mean = 4.63). When considering each aspect, it was found that the highest mean was the personality of the instructor and followed by quiz and evaluation, teaching technique, teaching material, and the characteristic of the AR application respectively. In teaching technique aspect, the level of student satisfaction toward teaching and learning management in the course increased when teachers used techniques to teach students to understand them more easily, including questions, debates, presentations, and etc.

Table 6 above describe the results for students learning satisfaction based on the teaching technique, the characteristic of the AR application, and the results of the satisfaction of the teaching material.

Table 6. The results of the satisfaction of the teaching material

	$\bar{x}$	S.D.	Level
Content is easy to understand	4.45	0.53	High
Content is clear	4.67	0.55	Very high
Content is consistent with objectives	4.59	0.53	Very high
Content is interesting	4.76	0.49	Very high

6 Conclusion and Future Works

This study examined student-learning achievements regarding the use of an AR mobile application. The experimental group showed a significantly better performance in learning achievements. Moreover, the study suggests that AR mobile system can extend learning outside the classroom and promote personalized learning. Students can enhance and improve their ability and this system supports teachers in handle and manages their course. In addition, AR is a valuable learning application: learners feel comfortable to use and learn when they had free time. In future experiments, we will be looking at how advanced technologies can support in learning preferences and interest of learners based on social networks, towards an adaptive learning for learners.

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Inspirational Messages to Motivate Students: A Human Centered Smartphone Application for Stress Relieve

Saad Almesalm(✉), Lucas Stephane, and Mohammad Algarni

Florida Institute of Technology, 150 West University Blvd, Melbourne, FL 32901, USA
{salmesalm2014,lstephane,malgarni2014}@my.fit.edu

Abstract. This paper is a continuation of earlier work on a major topic, i.e. "stressed students while in college" that is essential to both society and students. Based on previous work we have identified and analyzed the possible causes of stress that college students face. Three major factors (i.e. academic, social, and personal/family) are causes of stress for college students. It is important to note that this paper includes only the first three stages of the Human-Centered Design life cycle (Identify Needs, Research/Analysis, Design) related to students' motivation and mobile application development. Motivation is introduced and added as a key solution for stressed students. We propose a HCD smartphone application as a solution for the following questions: How important is motivation for students? To what extent inspirational messages help students with their motivation? How can a smartphone application help reduce/manage and be used to reduce/manage stress?

Keywords: Stress · Human-Centered design · Time management systems Rewarding systems · Social support systems

1 Introduction

The term stress is characterized as "a negative emotional, cognitive, behavioral and physiological process that occurs as a person tries to adjust to or deal with stressors" [1]. Stressors are "circumstances that disrupt, or threaten to disrupt, individuals' daily functioning and cause people to make adjustments" [1]. Stress is considered to be a serious matter on any campus. The consequence of being stressed can make students feel unwilling or unmotivated to do well in college. Also, students can act irrationally when they are stressed out. Making unwise decisions leads to poor learning quality. All these negative consequences could occur when students are under stress. Handling stress is different in terms of gender; female students tend to be more sensitive than male students. The same thing applies for both genders when it comes to coping with stress. Florida Institute of Technology provides counseling and psychological services for students on campus. This kind of support is important, but it may fail to reach students in an efficient time. Previous research [2] supports the idea that a smartphone application may be helpful to offer a solution for stressed students. HCD takes into account people, and

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ensures that they are involved in the design from an early stage to identify their beliefs, values, needs and constraints. Also, HCD considers anticipating how a user interacts with a system, and therefore attempts to fix problems early. If students are frustrated because of exams, or assignments, they will probably be worried and lose their concentration, interest and enthusiasm on schoolwork. Motivation can be the key to enable students to succeed in their academic life. Actually motivation supports students to achieve goals and gets students moving forward. The proposed application will assist students to succeed academically by providing them with the following:

- Motivate the student by sending inspirational messages
- Provide a good feedback to students based on their performance, based on alarm and reward features
- Contact trust circle for possible assistance

2 State of the Art

2.1 What is the Current Situation with Stressed Students?

If we compare lives today to our grandfathers' lives when they were students we realize that there has been massive information intensification. Students in particular experience great stress probably because academics have become more difficult. We study more difficult subjects and topics than our grandfathers used to study in their schools. Nowadays a culture has developed where parents try to send their children to expensive schools that offer the best possible education. There is no doubt that parents nowadays spend huge amounts of money by sending their children abroad to study and these are highly reputable institutions where competition is very tough [3].

Due to high competition there are many students who have to try again and again to get into their preferred university. It has never been this competitive to get into college and now students have to work very hard in order to get selected. The pressure to get selected in a university causes stress and students experience a lot of pressure nowadays to get admitted in a reputable institution in the first place. When a student gets selected, the pressure of paying for the college tuition fee can be a great cause of stress for many students when their families are unable to afford it. Also, when students cannot depend on their families for financial support, they either have to take a loan from a bank and/or work part time multiple jobs. As a result it becomes very difficult for students to manage at the same time their education, part time job(s), and personal endeavors.

2.2 How is Technology Used in this Area?

Any theory or ideology can have more than one perception and the topic discussed that has numerous perceptions is 'Can technology help us to handle stress?' On one hand many people would feel that technology actually increases stress, while on the other hand others believe that technology is a great medium to reduce stress and anxiety in daily life. The younger generation is the one inclined toward the major use of technology and there is no doubt that most of the youth lives revolve around technology use one way or the other. From waking up in the morning from your smartphone alarm to travelling, video calling and reaching the other corner of the world in the blink of an eye, technology has offered us numerous ways to deal with stressful situations [4].

There are many applications available for users that help them to deal with stress; however, there are only a few applications that are really designed to help students handling stress. FIT campus students need to have one of those applications due to the fact that it is supposed to help them decrease or at least handle stress while in college.

2.3 Cognition and Emotion

Stress in any form always affects every person in various ways, and in particular stress actually leads to cognitive decline in students. Stress effects on memory and other cognitive capabilities of the students like loss of memory sometimes results in hardly recalling recently learned information. Stress in a minimal amount can be a stimulating thing for a very short time, but continuous stress on students can affect their ability to concentrate and there have been research results that prove that stress interferes with students' ability to concentrate [5].

Today's students manage another identity in the digital world; social platforms are one more activity to keep up with stress. There are some other possible causes of stress on students [6]:

- Having more course credits
- Over eating
- Being angry in various situations
- Decreases sleep quality

2.4 Literature Review

Stress in students is one of the serious issues for which researchers have discovered appropriate data and reasons. There is no doubt that stress is now being considered as an essential and integral part of students' lives. There are a variety of stress types, which the students are experiencing in schools and colleges. Freshman year is considered to be the most stressful year among all years. First time in college students may face many issues such as competing with other students for grades or being afraid of AIDS. To simplify and provide a good view of the causes of stress, we have categorized the potential causes of stress into three groups: Academic, Social and Personal/Family. Also, we have provided the relative sub-causes of stress for each main factor as shown in Fig. 1.

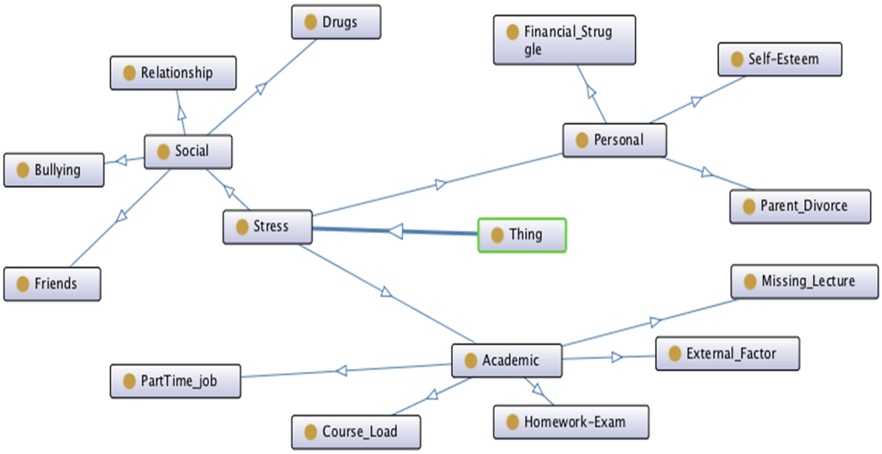

Fig. 1. Ontology of stress causes (Protégé screenshot)

2.5 Academic Stress

The primary objective for all students is to succeed academically. Many possibilities here could cause stress in college students. Not all students can be successful, and not all of them could get what they have planned for. There are reasons why students cannot succeed academically. Once they establish their goals in college, they put themselves under pressure since they have in mind that they need to achieve those; otherwise it could represent a consequent failure in their lives. Academic stress can be formed in many ways; having many assignments, taking more credits, working a part-time job and external factors such as playing video games or watching T.V. Parents can bring stress into their daughters or sons by pushing them to graduate with a higher GPA or encouraging them too much to get scholarships. Also, by criticizing their students, some professors may increase stress for some students. Understanding the possible causes of academic stress helps students to relieve and handle academic stressors.

Homework and Exams prove the students performance academically. Having too many assignments in a certain period of time or hard exams contribute to increasing students' stress. Sometimes students think that assignments or exams are easy and delay working on them, which causes stress. In this case, students need to understand the importance of priority. Once they prioritize their academic requirements, at least they have an idea of what they are supposed to do.

Course Load is very critical for some students. Some of them need to graduate early; therefore, they take more credits and they end up with a huge amount of stress. They do not only suffer academically, but they also suffer psychologically, physically and socially. "Increased coursework stress among students with higher academic success may be related to higher self-expectations for maintaining their high academic standing" [7].

Missing some Lectures is a great source of stress. When students miss more lectures, they feel that they are behind of understanding the materials as well as understanding the concepts of the course.

External Factors are major and highly important for students. Many students face this issue because they do not know how to manage their time. They have fun playing video games or watching T.V. or maybe they enjoy checking their online social media, but they really do not realize the effectiveness of leaving academic work behind. More specifically, if during final exams they keep doing all the fun activities, it often results in poor GPA or not being able to study as required.

Part-time job is another important stress factor for some students. Many students cannot afford the academic tuition and fees. They apply for part-time jobs, so they have additional income that could make their lives easier. However, this can cause stress in students by not being able to focus on school requirements. Being annoyed about financial issues, grades and academic performance can be a massive stressor in their academic lives. "More time spent at work can encroach on time otherwise available for studying" [7].

2.6 Social Stress

Being social is important for all humans, but it cannot be seen as all negative or all positive. When students get involved too much in college social activities, they may neglect academic related tasks. Therefore, students need to know how to balance their social activities. Furthermore, one of causes leading to student depression is not knowing how to handle social stress. Friends, bullying, a new relationship, or alcohol/drugs create social stress.

Friends are the most important aspect in social stress. They play a major by either increasing or decreasing stress. More specifically, female students tend to be more sensitive when it comes to social stress, meaning they feel that they compete with their classmates in almost everything, which makes them stressed all the time.

A new relationship is another factor that causes stress among students. Establishing a new relationship is stressful in college. "Giving up or changing new friendships and developing new ones is often a stressful activity associated with college life" [7].

Bullying is a serious matter that could destroy a student's life. This kind of factor can stay in student lives for a long period of time. Bullying can occur from parents, or anyone else, it could be formed in many possible ways. Making fun of someone is a type of bullying.

Alcohol/Drugs: Some students think that they can reduce social stress by drinking alcohol or taking drugs. They actually put their physical and mental health at more risk. Many students suffer from such practices and in some cases they may be forced in some ways to quit school.

2.7 Personal and Family Stress

Family plays an important role when it comes to stress. Parents cause stress in their children by pushing them to achieve good grades. Also, some students are the first in their families to join college, which can bring a consequent amount of stress. There are several reasons where some parents fail to provide the needed support to their children when it matters most, and the consequences include loneliness and loss of confidence, which could engender or trigger massive stress. Teens who lack moral, financial or emotional support or a combination of these on a consistent basis may become anxious and stressed, possibly resulting in effects such as cognitive function damage and poor results in their studies.

Fish and Chew [8] claim that the capacity of teenagers to learn effectively and improve their scholarly performances are linked to what their parents do or fail to do. This implies that the support that families give to teenagers can hugely determine whether they go on to succeed or fail in life. A family that offers support to teens regularly is invariably helping them to maintain a healthy growth both psychologically and physically. Families that cherish proper care for teenagers not only build up their personalities; their academic abilities are also enhanced.

Other reasons why teens may experience chronic stress include the following:

Low Self-Esteem: Teens with low self-esteem can develop massive stress over time. While several factors could induce low self-esteem in teenagers, the role of financial hardship, lack of moral and emotional support from parents and families, and the inability to build good relationships with others are very prominent. One way to know if a teenager is living with low self-esteem is the tendency to dissociate from others and prefer to live an isolated lifestyle. People with low self-esteem prefer to keep to themselves rather than share their concerns or problems with others. They lack the willingness to collaborate with fellow students even in important things such as scenarios where mutual learning can take place. Teens plagued with low self-esteem are consistently bound to reflect poor retention and weak academic ability.

Persistent Financial Hardship: Families that struggle to survive financially invariably impose undue stress on teenagers in the family. When there is not enough money to buy basic things of life let alone to buy materials that could enhance learning, teens may be forced to find a part time job, which may increase the level of stress already building up in teenagers. In Pfeiffer [7], the researcher claims that there are many teenagers who must work to support themselves through school. There are instances where teenagers not only work, but also work late into the evening thereby creating little or no time for effective personal studies needed to enhance academic performance in schoolwork. If such teens fail their exams, the tendency is that the failure might heighten their struggle and, hence, worsen the already chronic stress level.

Divorce or Abrupt Separation or continual bickering in Families: Where there is divorce in the family before the children can stand on their own emotionally, major changes may occur in their thinking that do not support personal drive for academic achievement. Besides, when teens are forced to make stressful changes in their conduct because of continual bickering in their families, this invariably result in lower self-esteem and poor performances in studies. Students from homes torn apart by divorce are more likely to be victims of social, emotional and academic trauma and hardships.

3 Motivation

There is a general agreement among scholars that motivation plays a crucial role in academic achievements especially in higher education. The findings of a research study claims that the desire for learning seems to shrink as individuals grow from childhood to adulthood [9]. A review of relevant literature indicates and shows that several attempts have been made to define motivation in general and academic motivation.

3.1 What is Motivation?

Guay et al. [10] explain motivation as the "reasons underlying behavior" and Latham [11] refers to it as a psychological process that enables an individual to act in a way whereby unsatisfied needs are met. In a clear and succinct way, Broussard and Garrison [12] define motivation as the attribute that allows individuals either not to aim for something, or to aim for something and achieve it.

In relation to academic pursuit, motivation has been defined as "enjoyment of school learning characterized by a mastery orientation, curiosity, persistence, task-endogeny, and the learning of challenging, difficult, and novel tasks" [13] Gottfried. However, Turner has a different view [14]: academic motivation is the voluntary application of top-notch self-regulated learning techniques such as being attentive, connected, focused, and inquisitive. By this definition, Turner [14] considers academic motivation to be tantamount to cognitive capacity contrasting Gottfried's definition, which regards academic motivation as non-cognitive with its peculiarities such as beliefs, perceptions, and attitudes.

All these attempts for defining motivation appear to highlight some important words such as beliefs, attentiveness, values, connection, individual interests, persistence, inquisitiveness, perceptions, and actions. A collection of all these concepts points to the fact that to be motivated implies that an individual is moved to aspire achieving a goal. Motivation gets people going. It stirs up curiosity and interest. Motivation promotes lifetime learning, which is why educators often find ways to turn the unwillingness to learn into some curiosity or desires to learn or to achieve a goal.

When an individual lacks the urge or an inspiration to act toward a desired goal, s/he is said to be unmotivated but there are different types of motivation and it is obvious that individuals don't only have different types of motivation, but also different amounts of motivation [15]. The distinctions between the types of motivation provided by empirical findings have offered important insights into how best to improve both the "developmental and educational practices" [15].

3.2 What Motivates Students in College?

Findings from a recent research study indicate that the reasons people apply to college can have a huge effect on their level of motivation and achievements through college. In a study conducted by Guiffrida, Lynch, Wall, & Abel [16] of the University of Rochester, the researchers attempted to "test the relationships between academic success and college students' motivational orientation conceptualized from a self-determination theory (SDT)". The findings show that students that were motivated to attend college by a desire for autonomy and competence appeared to obtain better grades throughout their years in college. The study also indicated that such college students demonstrated a higher level of persistence than other students of similar academic preparation and socioeconomic backgrounds.

The researchers also reported that the effect of different motivations varied depending on the socioeconomic group the respondents belong to. For example, high-income college students were found to be more likely to achieve higher grades based on their interest in studying certain courses than low-income students. Though low-income college students would want to study certain courses but if their motivation for applying to college was influenced by a desire to improve their income levels, that alone was found to be enough to impact their achievement in college in certain subject areas.

4 Solution

Figure 2 shows the process of the iterative HCD life cycle [17, 18]. It operates repeatedly into five stages (*Identify needs*, *Research/analysis*, *Design, Evaluation* and *Delivery*). It is important to note that this project is under development. Therefore, final tests and evaluations are not included in this paper.

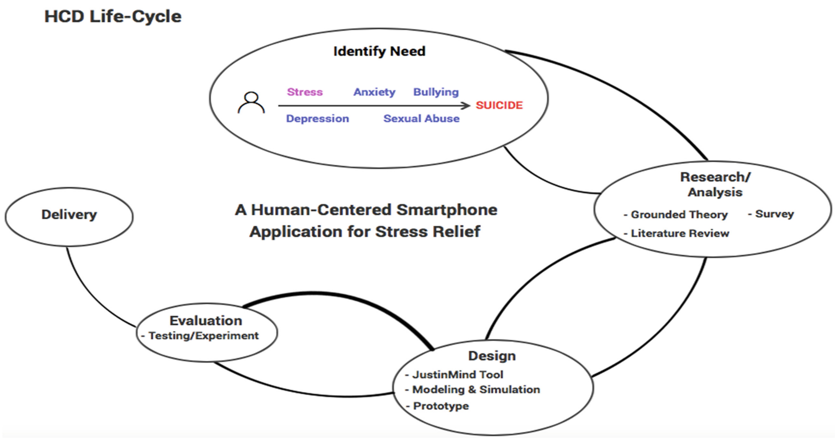

Fig. 2. Human centered design life cycle

In HCD, we involve users in the design stage as well as we perform multiple testing. This project has been divided into many stages and is presenting in this section only two stages discussed below. Also, we have completed two user evaluations for our proposed application and we are going to do the final one soon.

First Stage is discussed and explained in details in a previous paper [2]. A short summary is provided here to link the previous work with new one here. We conducted a survey (more than 100 respondents) to find out if stress exists at Florida Institute of Technology and we concluded with:

- 53% of FIT students feel stressed when their exam results are NOT excellent and 63.62% feel the same when their grades are low
- 29 respondents out of 100 report that they cannot concentrate when their grades are low
- Misunderstanding the materials, studying for an exam and working late on assignments are major factors that lead to stress
- Most of participants say that they talk to someone when they are stressed
- 52 respondents out of 101 agree that friends increase or decrease stress in college
- More than 50% of participants report that part-time jobs bring a lot of stress into their lives. Also, they say that they talk to someone when making a decision
- 43 respondents out of 95 reports that they need to increase their confidence level
- More than 80% of respondents agree that taking more credits hours, having a part-time job, and missing some lectures can be a matter of enormous stress
- 57.89% of participants say that relationships with friends can cause stress among students

Second Stage: The purpose of this stage was to perform usability testing of the prototype. The rationale behind this is to ensure the validity of the application and move forward in the implementation cycle. It consists of three parts: system usability scale (SUS), interfaces and main features of the application. The usability testing starts with a functional prototype (developed with the JustInMind tool). A set of tasks is provided to participants who are asked to follow them carefully. Participants have the prototype application on a real phone and are guided to perform the tasks. The approximate average time of completing this test was 15 min. The SUS scale used in this usability test has two main dimensions, which are learnability and usability. Question 4 and 10 represent the learnability dimension and the other 8 questions represent the overall usability [19]. Hence the results of the current application are presented below:

- *Learnability:* The results indicate that the majority of the respondents were positive about learnability. More than 70% of the respondents either strongly disagreed or disagreed when they were asked about the technical support and the prior knowledge required working with the software. This indicates that the majority of the respondents thinks that this application is very easy to use
- *Overall Usability*: More than 86% of the users either strongly agreed or agreed with the fact that they would use the application frequently, while 76.47% of the users thought that this application is not unnecessarily complex or considered the prototype as a simple one. More than 88% of the users thought that the prototype functions are very well integrated. 82.35% thought that people would learn this application very quickly. More than 87% of the respondents felt confident to use this application. Hence users provided very positive feedback related to usability. However, less than 60% of the users thought that the prototype had few inconsistencies, which is an indication that a reasonable percentage of users found inconsistencies in the prototype. Also, less than 50% of the users had some sort of a disagreement with the fact that the prototype is not very cumbersome or awkward to use
- *Graphical user interface*: More than 75% of the users thought that texts are readable and more than 82% of the users had some sort of an agreement with the fact that the

screen flow sequence is helpful. However, less than 65% of the users strongly agreed or agreed with the fact that colors are useful and the size of the buttons is good. Also, more than 23% had some sort of disagreement with the statement that colors are useful. These statistics indicated that the application needs color and button size improvements

In continuity with the prototype, the current version of the application (developed in Swift on iOS) is to provide functionalities that help FIT students to be able to handle stress while in college. The application is constructed to perform three main functions: Remind, Check and Reward. These functions are designed based on two HCD smart approaches, i.e. Time Management and Social Support. To properly use the application, students need to input their academic requirements including assignments, exams or project details. The application will store their academic data and will do the following:

– Remind students of their upcoming events
– Check with them about how they did in each event
– Reward students based on their performance by sending inspirational messages

Figure 3 shows the real GUI of the application and what each one contains of and how they are performed.

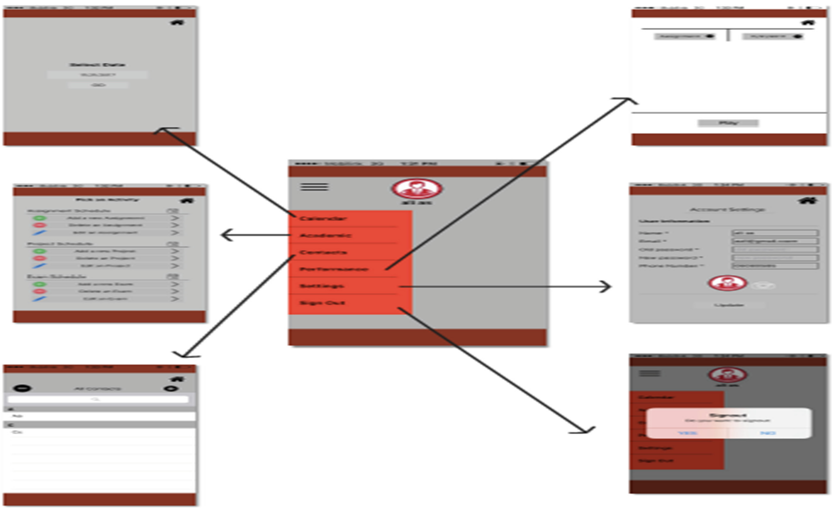

Fig. 3. Smartphone application GUIs

5 Conclusion

College students face stress and it is not surprising that almost all campuses in the U.S. and other countries have the same challenge. Stress is a common issue in college life. The main purpose of this paper was to link the previous work and show current improvements of the entire project. Based on previous work, we have categorized the sources of stress into three factors: Academic, Social, and Personal/Social. Also, we identified motivation as a key factor for stressed students. The proposed application is designed to enable college students to handle stress in a more efficient way. The application will be available in Apple store soon and our next step is to perform a final usability testing to prove that our proposed solution is useful for college students.

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Capacity Building Through Strengthening Professional Skills in Engineering Graduates

Albertus Retnanto[1(✉)], Hamid R. Parsaei[1], and Boback Parsaei[2]

[1] Texas A&M University at Qatar, Doha, Qatar
{albertus.retnanto,hamid.parsaei}@qatar.tamu.edu
[2] Texas A&M University, College Station, TX, USA
b.parsaei@tamu.edu

Abstract. Engineering programs globally are rich in technical contents in order to meet and satisfy accreditation organizations requirements. However, most of these programs in recent years came to conclusions that most of students and graduates could be better served if engineering programs could include emphasis on professional or soft skills. Although some of these skills are required and often emphasized by accreditation bodies, mastering in them require vision, planning, and allocation of time and budget by academic institutions. Furthermore, these skills must be embedded in the curriculum from the freshman year. The State of Qatar, a small country in the Middle East, has developed and implemented a national vision for the country known as Vision 2030 [1, 2]. One of the major pillars in the national Vision 2030 is the Capacity Building by providing quality education and training for the nation in particular for the younger generation with the leadership aspiration. Texas A&M University has established a branch campus in Qatar and has been offering four engineering degree programs since 2003. This branch campus has been exceptionally successful in offering quality engineering degree programs with a high emphasis on developing and instilling professional skills in its graduates through a variety of opportunities created and implemented by the faculty. This paper presents some of these programs introduced by faculty to further build students' professional skills and review some of the outcomes achieved over the past decade.

Keywords: Accreditation · Communication skills · Professional skills
Student outcomes · Continuous improvement

1 Introduction

The State of Qatar is small peninsula which is located in the Persian Gulf and shares the land border with the Kingdom of Saudi and maritime borders with Bahrain Iran. Expatriates living in Qatar make 89% of its 2.6 million population. Qatar's national vision and its investment in human capital have been one of the primary reasons for six top-tier American institutions opened academic campuses in Qatar. At present, Texas A&M University, Cornell University, Carnegie Mellon University, Georgetown University, Northwestern University, and Virginia Common Wealth University offered a variety on

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non-competing degree programs including engineering, science, medicine, liberal arts, social and political science.

All branch American universities branch campuses in Qatar financially supported by the Qatar Foundation and located in one complex, Hamed Bin Khalifa University, formerly known as Education City. Texas A&M University opened the Qatar branch campus in September 2003 and has been offering four ABET accredited engineering degrees in Chemical, Electrical, Mechanical, and Petroleum. Since 2003, the campus graduated and awarded undergraduate degrees to over 800 candidates.

Once of the major strengths demanded by the local petrochemical industries and well emphasized by Texas A&M University is professional skills [3]. Due to joint investment of the Qatar government and the existence of many multinational companies in Qatar, strong needs were expressed by these companies to equipped graduates with strong communication, time management, leadership, and entrepreneurial skills [4]. Almost one hundred percent of students enrolled in Texas A&M University are bilingual with English being their second.

Communications are consistently emphasized through four engineering curricula, and students are required to take classes identified as "Writing" courses during their four education. Furthermore, some curriculum such as Petroleum and Mechanical Engineering one credit hour course devoted to technical communications, leadership, time management, and other professional skills development.

2 Technical Communication Courses

Students perusing Petroleum Engineering degree at Texas A&M University are required to register for PETE 436 Petroleum Technical Presentation. This is a one-credit required course in which Petroleum Engineering students work individually and investigate on a subject related to petroleum technology and are required to submit a formal technical term paper and make a professional presentation to classmates and members of the Petroleum Engineering Program Advisory Board. Students are responsible for proposing the topic, conducting independent research and preparing the presentation. During the course of semester, students are lectured and coached on technical writing, and professional presentation skills and their performance are measured by a set of rubrics developed jointly developed by faculty and members of the program advisory board. Students are required to make a 15-min presentation on a subject of their choice, commonly one involving an undergraduate research project, although students may choose to speak on any petroleum engineering topic. The formal student presentations, Student Paper Contest, in which Society of Petroleum Engineer-style presentations, is a day-long event and best presentations and best papers are recognized for awards sponsored by various oil and gas companies.

At the end of this course, students will be able to:

1. Gather information, make calculations and/or analyze data to achieve the specific objectives of an independent study of a petroleum engineering problem

2. Prepare an Introduction for a paper/presentation, consisting of problem statement, review of previous work presented in the literature, need for further study, and study objectives
3. Prepare a Methodology section for a paper/presentation, including tasks, data and methods employed, and assumptions made in the study
4. Summarize the results of an independent study in appropriate textual, tabular and graphical forms, consistent with engineering and Society of Petroleum Engineers (SPE) presentation standards
5. Prepare a Discussion section for a paper/presentation, including analysis and interpretation of study results
6. Draw appropriate conclusions from an independent study consistent with project objectives and properly supported by data, calculations and/or analysis
7. Identify limitations of the work and prepare recommendations for further work, if appropriate, supported by evidence presented in the results and discussion of the study
8. Identify the significance, potential benefits, and possible applications of the results and conclusions of your independent study
9. Prepare a References section, consistent with the SPE style guide, listing all literature cited in a technical paper
10. Write a title and abstract for a paper/presentation of an independent study consistent with SPE standards
11. Prepare Microsoft PowerPoint slides and poster for an independent study that can be used in an oral presentation to persuade others that the study results, conclusions and recommendations are correct and useful
12. Present the result of an independent study orally to a panel of practicing engineers from the petroleum industry and faculty members in 10 to 15 min, using PowerPoint slides

As additional, students are required to write a technical paper for the independent study consistent with Society of Petroleum Engineering standards on a subject related to petroleum technology. All students need to prepare at least 2,600 words that include introduction for the paper consisting problem statement, review of previous work presented in the literature and study objectives, methodology and technical content for the paper on a subject related to petroleum technology, and discussion, conclusions, title, references, abstract for the paper. During the semester, students receive feedback on their writing progress thru in-class workshop, peer review, written and oral comments from instructor.

The Mechanical Engineering Seminar, MEEN 381, is one of the two writing (W) courses required for students to receive an undergraduate degree in this discipline. This intensive writing course is comprised of several components. These include presentations by practicing engineers and faculty addressing:

1. Professional responsibilities, opportunities, job types available to Mechanical Engineers.
2. Various career paths available to Mechanical Engineers.

3. The importance of technical skills in being a successful and effective Mechanical Engineer.
4. The importance of non-technical skills, such as communication, ethics, attitude, and team work, in being a successful and effective Mechanical Engineer.
5. Techniques for effective written and oral technical communication.
6. Effective listening and feedback on effective written and oral technical communication.
7. The impact of engineering on society and global issues.
8. The importance of knowledge of contemporary issues in being an effective Mechanical Engineer.

Speakers representing a cross-section of industry in Qatar are invited to deliver presentations on various subjects directly tied to subjects listed above and many more. At the end of this course, students should be able to:

1. Appreciate the varied opportunities available for professional practice in Mechanical Engineering.
2. Appreciate the various types of industries, job types, and career paths available for graduates in Mechanical Engineering.
3. Appreciate the importance of non-technical skills, such as communication, team work, and attitude, in professional success.
4. Gain an understanding of professional and ethical responsibility from the experiences of practicing engineers.
5. Demonstrate an appreciation for life-long learning and compose a reasonable plan for engaging in life-long learning, including professional engineering registration.
6. Articulate the importance of practicing in a professional, ethical manner.
7. Deliver an accurate and effective ten-minute oral presentation on a technical topic.
8. Compose an accurate and effective two-page written report on a technical topic.
9. Be able to cite examples of the global and societal impact of engineering.
10. Have an added appreciation for contemporary issues.

Students are required to write a page long reflection their take of the subject presented and why the subject is important to mechanical engineers and society as a whole. Furthermore, students are provided by several templates developed internally for preparing memos, technical reports, letters of reference, etc. for a variety of writing assignments. The MEEN 381 course also requires that students prepare and submit a well-researched term paper focusing on contemporary issues in two phases in the semester. All students are required to prepare a 200-word abstract by the third week of the semester describing the topic chosen for their term research papers and its significance. The review of the first draft including the instructor comments returned to students for improvement by the middle of semester. All comments and suggestions for the improvement must be addressed in the final submission. All students are required to make a presentations over their topics. The presentations are assessed and evaluated by the course instructor and one faculty from the liberal arts.

The external speakers identified to deliver presentations to this course are carefully reviewed and normally invited a few months prior to beginning of the academic semester. A handout stating the objectives of the course and the potential focus and key areas of emphasis is provided to the invited speakers at the time when an invitation is extended.

The observations and data collected over the past eight years clearly demonstrate that students writing and verbal communications as well as their professional (soft) skills significantly improve after the completion of this course. These results could also be attributed to the course structure and its primary emphasis on communications and professional skills development.

Students' evaluations of this course have clearly been demonstrating students' interest in further improving their communications and professional skills. Many students clearly see the direct relationships between having good technical and professional skills and advancement in the organizational hierarchy.

3 Conclusions

Communication skills including writing and oral presentation necessary for engineering graduates to meet the industry expectations have been well documented in academic literature. In addition to writing skills, the industry expectations have grown to further focus on time management, understanding entrepreneurism, and public speaking among many others. These challenging requirements will further be magnified in international campuses due to the variety of languages practiced in that community. Continuous encouragement and repetitive demand on writing and acquiring public speaking skills have proven to be instrumental in developing well-rounded engineering graduates with both technical and professional competence to perform well and meet the global expectations of multinational industries.

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Sense and Sensibility in Fashion Design Education

Ines Simoes(✉), Mário Matos Ribeiro, and Nuno Nogueira

Research Center for Architecture, Urbanism and Design (CIAUD), Lisbon School of Architecture, Lisbon, Portugal
ines.sa.simoes@gmail.com, mmrdesigner@gmail.com, nunonogue@gmail.com

Abstract. This article discusses the conventional function of drawing as a tool to generate ideas and solve problems in Western art and in art and design higher education. The problem of design ideation is also examined regarding Generation Z fashion students and their seeming inability to express ideas through drawing. In our view, this is not because they don't have graphic skills but because they exclude from consciousness much of the clothes details, a circumstance that is inversely proportional to their access to fashion images via digital devices as well as clothes via fast fashion stores. Our aim is not to discredit fashion education's orthodox approach altogether, but to contribute to its redesign toward a more hands-on methodology. Thus, we present six exercises that use drawing in combination with other exploratory techniques, as their effectiveness proved their right to become part of the curriculum of our BA in Fashion Design.

Keywords: Drawing · Generation Z · Fashion design's orthodox approach
Alternative exploratory approaches

1 Introduction

Art and design higher education traditionally count on the students' drawing skills to communicate their ideas. Counting on the students' ability to draw is senseless, as educators should remember that "many people give up drawing altogether at [the age 12 or 13], often through frustration. Their creative ambitions outrun their technical abilities. As a result, most adults have the graphic skills of a young adolescent" [1]. As a matter of fact, students applying to the Lisbon School of Architecture BA in Fashion Design are selected on the basis of their grades and test scores instead of a portfolio and interview.

The above circumstances raise a few problems regarding today's generation of students (Generation Z) – who were born after 1995 and consequently grew up in the digital age and therefore are addicted – to being bombarded by visual stimuli and to have instant access to a colossal amount of information shown in their electronic devices. Owing to this phenomenon they consider drawing a time-consuming process.

One of the problems is their attention span, which is believed to have shrunk to eight seconds [2]. According to Ron Burnett, understanding how to maintain attention

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for a long enough time so that "perception, thought and insight can be given time to develop" is the greater issue for contemporary practices of literature and art [3] and logically design education.

On the other hand, the flattened out upbringing that Generation Z students are subject to excludes from their consciousness much of the interlocking elements that produce the whole 'picture' and therefore their design ideas are seemingly unsophisticated as well as poorly communicated through drawing.

Thus, exploring ideas solely through drawing is an unproductive approach. It is crucial to come up with alternative approaches, grounded on the understanding that "we can know more than we can tell," as Polanyi puts it [4]. We, educators, must remember that Generation Z, just like everybody else, have a long experience as dressed bodies and, as fashion design students, they have instant access to myriad fashion images. It is up to us to provide the means for them to relate their embodied knowledge with the process of designing fashion products.

We believe that hands-on activities are more efficient than listening to formal lectures and watching demonstrations, as students would engage actively with their bodies rather than depending on their passive capacities to retain 'abstract' information.

Moreover, if fashion design education would bring into play the full engagement of affective domains, including feelings, attitudes and emotions, the cognitive bond between all the implicit and explicit information acquired during the learning process would be strengthened. To nurture the students' sensory intimacy with physical products would certainly enhance the design process from ideation to the tangible product.

This is not to say that drawing, by itself, should be rejected. On the contrary. We must enable students to understand how drawing is a way to quickly explore concepts, using traditional instruments paired with faster, more engaging and inspiring techniques.

2 The Problem of Drawing

Art and design higher education traditionally count on the students' drawing skills to communicate their ideas. This focus on drawing is not preposterous since, from the cognitive development perspective, drawing was, for most adults, a natural process that prefigured writing, an activity that was spontaneously engaged in an attempt to understand the environment and the experience of it [5]. On the other hand, from the Western art perspective, drawing was the medium artists elected to generate ideas and solve problems "in preparation for the creation of a painting or sculpture" [5] from the medieval period to Modernism.

Despite the fact that the essential nature and uses of drawing began to be re-examined and investigated since Modernism [5] – with the aim of viewing it as a discipline in and of itself–, its function as an intermediate stage has been reiterated by art and design higher education until today. Nonetheless, drawing is historically associated with skill, technique and naturalistic rendering, a combination of abilities that contributes "to the perception that drawing is a specialist rather than a universal activity, which should only be taken by those with evident skill and ability" [5].

As a matter of fact, "many people give up drawing altogether at [the age 12 or 13], often through frustration. Their creative ambitions outrun their technical abilities, most adults have the graphic skills of a young adolescent" [1]. Therefore, our argument as fashion educators is that counting on the students' ability to draw is senseless, particularly because students applying to the Lisbon School of Architecture's BA in Fashion Design are selected on the basis of their grades and test scores instead of a portfolio and interview.

Even though those entry requirements are unconnected with the advent of computer aided design systems and vector graphics editing software – which have weakened the importance given to hand drawing by most current students –, why, then, the role of drawing "in education remains critical […] to the creative disciplines in art and design for which it is foundational" [6]?

According to Sennett [7], the merits of drawing by hand as opposed to computer generated drawings, are related to the type of physical experience that occurs and the degree of maturation it provides: its tactile, relational and open-ended inherent character prompts the artist or designer to think about the object's materiality. "Tedious though the process is" [7], the object becomes ingrained in the mind, head and hand working together in search of the best solution.

3 The Three Fashion Drawings

In the fashion world, new designs are traditionally presented in the form of drawings before they're actually cut and sewn. This means that, for the fashion industry and fashion education, "drawing has a projective condition, always ancillary, anticipatory and pointing to the future outcome" [5].

Drawing is, thus, a tool not the end-product. In that quality, drawing is traditionally a big part of a fashion designer's work, and therefore an essential skill. In fashion education, in its attempt to mimic the quotidian of fashion studios, drawing is one of the fundamental parts of the design process, "often given a lot of time and attention as the ability to visually describe [the] designs and develop them […] with originality and personality" [8].

Traditionally, fashion drawings comprise three categories, all of them employed by students throughout a course project: exploratory drawings, flat sketches and illustrations. The first category concerns the series of freehand sketches done with aim of trying out ideas, in a process that allows "to revise the work and redraw to develop a composition, working through problems as they occur" [9]. The second category consists of the technical drawings, otherwise known as flats, done with the aim of showing how they look in themselves, as they represent "all the construction details, such as seams, darts, pockets, fastening and topstitching" [8]; the visual language used in flats conform to standard conventions and in proper proportion so that all the information is easily and clearly understood through the production process. The third category consists of final drawings done with the aim of "capturing the spirit of the clothes. [They] can be used to express a mood or give the clothes context" [10]; termed as illustrations, they usually represent the clothes on a figure to visualize how they look on the body.

The possibility of seeing how clothes look in themselves before they're cut and sewn includes the consideration of various visual aspects, such as shape, line, color/value and texture (which totalize the elements of fashion design) as well as proportion, scale, balance, unity or harmony, rhythm and emphasis (which totalize the principles of fashion design); combined in the drawing, the principles and elements applied to each garment enable the students to perceive how well they relate with each other. Seeing how clothes look on the body before they're cut and sewn includes the consideration of the phenomenon of gravity and, to some extent, human anatomy; combined in the drawing, the understanding of both instances enable the students to perceive how the selected fabrics drape, how the shape holds and how well body and clothes relate with each other.

Each of the categories mentioned above involves different mindsets and types of rendering, but even the activity of exploring through drawing, despite exhibiting a rough, incomplete look and done swiftly, involves a high level of graphic skills [11] inversely proportional to its type of representation.

Furthermore, all three categories depend on the students' stock of visual and tactile information of actual clothes, since all of them involve drawing from 'memory' what does not exist yet, i.e., evoking a variety of details sufficiently similar to the ones they want to include in their designs.

From the neurophysiology standpoint, drawing from memory is grounded on two perceptual-motor interactions separated in time: in the first occasion, eye and brain work together to guide eye movements during observation; in the second, head and hand work together to reenact, while drawing, the eye movements done in the first occasion [12]. In view of that, drawing from memory for someone lacking images of clothing details stored in the brain is a difficult deed, if not altogether impossible.

4 Generation Z and the Problem of Fast Fashion and the Digital World

Generation Z students – born from the mid-1990s to early 2000s –, today's undergraduates, seem to be unable to relate their own experiences as dressed bodies with the process of designing fashion products.

The reasons for this apparent inability may lay in the fact that fast fashion, a phenomenon that came to the fore in the late 1990s, is the current consumption practice. For one thing, the quick manufacturing of clothes based on current high-cost luxury fashion trends, produced with low quality/low-cost fabrics and sold at an affordable price encourages a 'throwaway' attitude among users [13]. New clothes are available every few weeks and correspondingly discarded, a pace that results in long-run indifference (as though old clothes cannot be affectionately regarded) and excludes from consciousness much of the details (as though clothes are merely perceived as inkblots). In truth, fast fashion is grounded mainly on visual stimulus rather than tactile stimuli, causing the sensory and sensual qualities to disappear from artefacts [14], namely fabrics and clothing.

As true digital natives, Generation Z students have never known life without Internet, cell phones and other electronic devices. They spend approximately nine hours a day on entertainment media, excluding screen time spent at school or for homework [15]. Although they were born a few years before the boom of social media they don't remember "a world in which letters were printed and sent, much less hand written" [16]. They have lived their entire lives with instant access to a colossal amount of data about any topic that crosses their minds – without questioning its accuracy, losing interest quickly [17] – and have never known the challenge of researching using analogical tools. They avoid tasks that take too long because that implies concentration – an impossible deed since their attention span is believed to have shrunk to eight seconds [2].

The problem, regarding Generation Z students, is that the consumption of fast-fashion and the digital world they live on tend to flatten the magnificent, multi-sensory, simultaneous and synchronic capacities of imagination by turning the design process into a passive visual manipulation [14]. Consequently, the design ideas they produce through drawing reveal, more often than not, the poor long-term memory of fashion products.

It's as if, in their shopping sprees, the – voluntary and involuntary – eye movement trajectories performed by Generation Z students when viewing garments or accessories is done so inattentively and for such a short period of time that prevents them to track enough visual and tactile stimuli – like shape, texture, proportion, balance, seams, darts, pockets, fastenings and topstitching –, a circumstance that undermines their capacity to communicate ideas through drawing.

However, it is not sufficient to look at fashion products, meticulously or not. Considering that clothes are, by definition, wearable, Chon [18] defends that fashion knowledge must be "developed through physical, conceptual and emotional interactions with products." In actual fact, Generation Z students, like everybody else, have a long experience as dressed bodies.

That, and that alone, means that they "know more than [they] can tell" [4], a type of human knowledge termed as tacit knowledge. An example of this faculty is when going a second time to a store to purchase an item that attracted us before we can identify it immediately, although we cannot describe it in words. The truth is that, for most of us, the details are indivisible from the whole and only when given time to dwell on the details "we may be aware of them in their bearing on the comprehensive entity which they constitute" [4].

5 Fashion Design's Orthodox Approach

For some time now, our mission as fashion design educators is to overturn the misconceptions that Generation Z students have about the design process. In reality, the misleading notions they have before entering college were obtained from social media and blogs, which, more often than not, provide superficial information about how the fashion industry develops design ideas.

However, Web platforms are not the sole sources of superficial and fictional information because most fashion design educators and the majority of the books designed to assist fashion design students still embrace and implement the orthodox approach to teaching/learning, in use since the 1980s, comprising three sequential steps: research, mood board development and ideation.

The first step is rooted in primary and secondary sources of information that should be translated into concrete or abstract concepts. In our view, this particular research step is no longer pertinent because Generation Z students, at this stage of their education, do not have enough intellectual flexibility, a circumstance that prevents them to translate "the objects [they] have drawn directly from, for example, […] a museum of natural history [and] the findings of other people […] found in books, the Internet, journals and magazines" [8] into intelligible concepts.

The second step is specifically non-product and assembles a range of images of artifacts, colors, fabrics, etc. creatively arranged "in a calculated and planned effort to link content to a particular theme or idea" [19]. Although Generation Z students are eager to bring together beautiful and avant-garde images and able to accomplish balanced compositions, they are unable to convert the created mood and the explored concept into products, a circumstance that is possibly attributable to their short attention span, causing the constant shift of ideas and design directions.

The third step is, by definition, an iterative process that depends on the capacity of educators to guide students into identifying and explore potential ideas and discard irrelevant ones. When educators fail to understand the merit of exploratory drawing and students 'fail' to be innately focused – thus failing to willingly produce "hundreds of design sketches, with many variations and subtle changes" [8] –, the end result is an assortment of unsophisticated, unrelated designs, incapable of forming "a coherent, well balanced and harmonious collection" [8].

6 Sense and Sensibility: Alternative Approaches

However, our aim is not to discredit or disregard the orthodox approach. Instead we aspire to contribute for its redesign toward a more "hands-on and process-driven design methodology of form generation […] coupled with explorations into material behavior and usability" [20]. For that purpose, we selected six exercises, clustered into three categories, that were progressively introduced or reallocated to a different academic term or year since the Fall Semester 2014[1] in view of the students' knowledge and skills, as their effectiveness proved their right to become part of the program curriculum.

The first cluster respects the exercises that allow finding solutions not sought for, use three-dimensional techniques and rely on visual and tactile stimuli, namely,

Designing by Draping. Let the Self emerge without prejudice is the motto of this exercise. Its method involves basic-level skills but it may be engaged at any stage of the BA program. In any event, students drape basic geometric shapes – rectangles, squares, circles and quadrants –, one at a time, on drawing mannequins to generate a minimum of thirty garments. The prerequisites are to use a single piece of fabric for each garment, to be unconcerned about the garments typology, function and potential customer, besides having to keep the geometric shapes as intact as possible throughout the process. To adapt the geometric single shapes to the three-dimensional, sectioned,

[1] When new guidelines were designed for the Fashion BA of the Lisbon School of Architecture.

articulated mannequin, students create folds and slits, exploring myriad combinatorial possibilities. At the beginning, the exercise's constraints seem senseless but at one point in time the students' design identity surface spontaneously, producing a family of garments that have a number of core properties in common.

Dissect and Edit. This exercise is based on Ruby Hoette's [21] research, *collection*, in which garments were unpicked along their original seam-lines, in order to separate their components and rearrange them into new formations, creating a series of collaged garments. The act of 'dissecting' pieces of clothing allows students to become conscious of the construction process of clothes, while the various detached components, grouped in relation to their category – i.e., sleeves, collar, pockets, cuffs, etc. –, helps them to structure a tangible fashion lexicon. The process of rearranging these components gives students the opportunity to instantly explore solutions not foreseen and "activate [their] tacit knowledge embedded in the practice of curating [their] wardrobes and in the daily act of dressing" [21]. The intuitive and tactile nature of the process and the demanded skills makes this exercise especially suitable for students in an early stage of the BA.

The second cluster respects one exercise that allows finding solutions not sought for and another one that allows working on solutions devised beforehand; both use two-dimensional techniques to achieve three-dimensional shapes as well as relying on visual and tactile stimuli, namely,

From Micro to Macro. This exercise, which corresponds to the first step of the collaborative collection designed and manufactured by senior students, resembles the Dissect and Edit exercise although, in this case, students use their flat patternmaking and sewing skills to produce a visual and tactile archive of three-dimensional full-scale samples, exploring variations in shape and proportion as well as different fabrics, prints and textures. Like the Dissect and Edit exercise, the ideation process is similar to the process of solving a jigsaw puzzle, as it involves assembling the assorted samples until the collection's direction is identified. The precise look of 150 garments and accessories is further developed to ensure that the various outfits, capsules and the collection are coherent. In this manner, the orthodox design process is inverted, as it focuses on components and details instead of whole garments and outfits, as ideas are developed through tangible samples instead of exploratory drawings.

CC41. This exercise is based on the Utility Clothing Scheme, introduced by the British Board of Trade, in 1941, for economic aid during the war years, which regulated the amount of material and labor to be used in the construction of clothing. Designed for third-year students, the aim of the exercise is to deconstruct and redesign several iconic tailored clothes – such as, the trench coat, pea jacket, duffle coat, boating blazer, military jacket and tuxedo jacket –, guaranteeing that the solution follows the imposed restrictions on fabric length, number of seams and buttons, among others. To find the best solutions to the problem, the ideation process uses the flat patterns of the iconic items made earlier to identify which seams can be eliminated, how the amount of fabric can be reduced, etc. Lastly, the presented solutions must display sufficient core properties of the iconic items so their style is still recognizable.

The fact that the aforementioned exercises do not follow the orthodox approach to design ideation does not mean that drawing, by itself, should be rejected. On the contrary. We endorse Sorger and Udale [10] when they spell out that "ideas can be worked out three-dimensionally [...], but even this method of designing requires development on paper at some stage."

We also defend that some exercises that use drawing as a visual tool with which to find solutions not sought for or briefed beforehand could be valuable, providing they are cleverly designed to counteract the misconceptions Generation Z students have about what is the proper fashion design ideation process and to lessen their propensity to think that choosing a concept or theme is essential for developing a good and unique collection.

We thus trust that the following exercises, within the third cluster, demonstrate how drawing can be such a tool, namely,

Collages. This exercise is based on Simon Seivewright's *idea generation exercise* [8], in which images of unrelated objects – among themselves and to fashion – are grouped together on figure templates, allowing the students "to see immediately the design potential" of the collaged figures [8]. Then, from each collage's suggested garment typologies and styles and the hinted components and corresponding details, three variations are created, taking into account the principles of design – shape, line, color/value and texture – along with the elements of design – proportion, scale, balance, unity/harmony, rhythm and emphasis. The exercise continues by mixing together features of each design, reiterating the process with the resulting designs until a collection of garments that share a number of core properties is obtained. Although the process relies predominantly on drawing skills, the open-endedness, easiness and exploratory nature make this exercise particularly suitable for students in an early stage of the BA.

Lottery. Based on the exercise *Geringonça*, by Pedro Cortesão Monteiro [22], which involves thinking outside the box "to find a functional solution for an object made of the improbable sum of various parts." Akin to a lottery system, 36 variables are arranged into 6 columns and 6 rows, specifying the body part to dress, the garment component to design, its color combination, the fabric's decorative technique, type of clothing fit and the type of material to use. Using the students' ID numbers, the six variables to work with determine, for example, to dress the legs loosely with a yellow and purple Peter Pan collar made of pleated neoprene. The table is done in such a way as to present "problems 'with no prior existence,' with solutions unable to be found on the Internet" [22]. The level of knowledge and intellectual flexibility required makes this exercise suitable for third-year students.

7 Conclusions

Since the medieval period of Western art that drawing is used as a tool to generate ideas and solve problems, an activity that involves expertise and talent. Therefore, art and design higher education still count on the students' drawing abilities to communicate their ideas. However, students applying to the Lisbon School of

Architecture's BA in Fashion Design are selected on the basis of their grades and test scores instead of a portfolio and interview. This fact alone might explain why the majority of Generation Z students communicates their design ideas through drawing rather poorly, although it doesn't explain why their design ideas are generally unsophisticated.

Given that, we question why drawing is still given so much emphasis, why is it still considered the most important tool for design ideation. Fashion education programs, in their attempt to mimic the quotidian of fashion studios, dedicate special attention and time to nurture the students' ability to express their ideas through drawing. In reality, the fashion world presents new designs in the form of drawings before they are cut and sewn, a circumstance that justifies why drawing is an essential skill for a fashion designer to master. Typically, exploratory drawings, flat sketches and illustrations are made before clothes are cut and sewn, each of them requiring different types of rendering, but all demanding a high level of graphic expertise.

Nonetheless, just like in art, fashion drawing is a tool to generate ideas and solve problems, not an end in itself. As a tool to explore and represent new fashion products accurately before they are cut and sewn, drawing depends on the stock of visual and tactile information one has – a circumstance that allows to evoke memories of details of actual clothes and, therefore, new ways to combine and redesign them.

The seeming inability of Generation Z fashion students to represent fashion products through drawing is, in our view, not because they don't have graphic skills – even if it's true since, like most people, they may have given up drawing in their early teens – but because they exclude from consciousness much of the clothes details, a circumstance that is inversely proportional to their access to fashion images via digital devices as well as clothes via fast fashion stores.

This is at odds with the fact that, with the new millennium, many students entering college choose Fashion Design above all other study options, which should mean that they were more informed about fashion products and more willing to learn the implicated skills. The problem may pivot around the fact fashion education still uses the same teaching/learning methods from the 1980s. The importance given to research, mood board development and ideation – three sequential steps of the orthodox approach – do not seem to help this new generation of students to develop intellectual flexibility and to bring their tacit information about fashion products to the fore. This fact paired with the superficial information students retrieve from the Internet demands immediate attention and proper care.

It is essential, therefore, to adopt a more hands-on approach, to implement techniques and exercises that might be more engaging, intuitive and inspiring to help students expand their stock of visual and tactile information about fashion products and convert their embodied experience into explicit knowledge.

Our aim is not to discredit or disregard the orthodox approach, instead to adapt it to Generation Z students. We propose six exercises that use drawing in combination with other exploratory techniques, as their effectiveness proved their right to become part of the program curriculum, as most of our current students expressed their satisfaction regarding the outcome of hands-on exercises, thus concluding that drawing is not the one and only tool for fashion design ideation.

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Certain Approaches to Automated Designing of Competence-Oriented Models for Knowledge Engineers Using the Tutoring Integrated Expert Systems

Galina V. Rybina(✉) and Elena S. Fontalina

National Research Nuclear University MEPhI, 115409 Moscow, Russia
galina@ailab.mephi.ru

Abstract. The development of engineering knowledge led to the emergence of new professions, which are widely popular professional competence and personal qualities. This paper provides a methodological and technological experience in automated construction competence-oriented models specialists in the field of knowledge engineering, in particular, specialists of the profession "system analyst" with the use of tutoring integrated expert systems.

Keywords: Tutoring integrated expert systems
Competence-oriented model of a specialist · Engineer knowledge
Student model · AT-TECHNOLOGY workbench

1 Introduction

Implementation of advanced concepts of transition to new professional tutoring and training computer-aided technologies for IT professionals implies a flexible common use of professional educational standards and the automated designing technology for the intelligent tutoring systems (ITS), in particular, tutoring integrated expert systems (IES) of various architectural types [1, 2]. It is ITS architectures that procure the advanced tools of the students' intelligent tutoring, monitoring and testing and help shape the competence-oriented models for future professionals as the ultimate result.

It is noteworthy that the competence format of the new Federal State Educational Standard for Higher Professional Education [3] envisages that the professional education quality should be assessed based on the graduate's competencies meaning the integral result shown after the education plan completion. The young professional's competencies shall enable him or her to successfully work in the selected occupation area and acquire social, personal and general cultural qualities that promote his/her social mobility and sustainability on the labor market.

In terms of the European Educational System, the notion of "competence" includes, besides the cognitive, operational and technological component, incentive, ethical, social and behavioral components that determine the system of the graduate's values as well [4]. Thus, as concerns the knowledge, skills and capacities widely used in the current Federal State Educational Standard for Higher Professional Education, the

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competence-oriented models for professionals of different levels have a comprehensive, integral nature that includes the set of knowledge, skills, capacities and social and personal qualities [5]. Accordingly, graduates' competencies improve in case of gradual completion of bachelor and master educational programs.

The key problem is to make sure that the professional standards, in this case IT standards, will not remain a certain methodical basis, but will be pro-actively included in the automated shaping of future professionals' competencies that show what the student will know (i.e. the student's theoretical training) and be able to do (i.e. ability to leverage theoretical knowledge in addressing practical tasks) upon completion of a certain educational plan (direction) and how well he or she is able to apply the knowledge, skills and personal qualities gained at the university for successful professional activity.

Similar experience has already been gained in the Cybernetics Department of MEPhI when training professionals in Applied Mathematics and Informatics, which is currently pro-actively used as part of the Software Engineering direction. This was facilitated by the research and development project of creating the intelligent technology for building a broad TIES category, including tutoring IES and web-IES [1, 2, 6].

The problem-oriented methodology of TIES designing [1, 2] and its supporting unique workbench type tool, AT-TECHNOLOGY workbench, enable the development of state-of-the-art IES and web-IES with advanced intelligent tutoring, monitoring and testing tools for students, through designing and software support to the individual competence-oriented models of students (with the view to the personality's psychological profile), adaptive tutoring models and explanations, models of course/discipline ontologies. etc. The main provisions of the problem-oriented technique and the description of functional options of various versions of AT-TECHNOLOGY workbench are available in several monographs [1, 2, 7] and numerous papers, e.g. [6–8, 14] etc.

In order to implement intelligent tutoring based on designing and use of tutoring IES and web-IES in the training process, the professional standards for Information Technologies [5] were rather efficiently used as the basic information methodical resources when designing professional competence models, in particular, for such occupations as "programmer", "system analyst", "IT system specialist", "system architect" etc.

Such occupations as "system analyst", the demand for which is coming closer to that for programmers in the contemporary market for high information technologies, should be specially designated among the listed professions. At present, these professionals in knowledge and technologies of designing intelligent systems are called differently: knowledge engineers, knowledge analysts, cognitologist engineers, task setters, and much attention is paid to their training. For instance, the systemic view of training the knowledge engineers is available in [15, 16] where the authors' experience in training knowledge engineers and business analysts in the last 15 years is summarized. Many interesting findings on this problem are available in [17–22] and other papers.

In general, as the experience of development and use of tutoring IES and web-IES in training suggested, the following objectives are the critical in shaping the professional and general competences are:

- Selective sampling at each tutoring stage (bachelor, master) of the knowledge, skills and capacities that the students must gain (applied course/discipline ontologies, generalized ontologies of individual training fields are used);
- Improvement of the monitoring and testing techniques, both for the purpose of shaping of current competence-oriented models for students and upon tutoring completion (web-testing of the students with generation of options based on the genetic algorithm is used);
- Efficient accounting for personal features of the students in selecting and shaping of the learning strategies and impacts, including the development of special corrective training impacts intended to develop the student's individual personal features (the students' psychological testing findings together with different types of learnings interactions are used);
- Use of additional (repeated) tutoring based on the identified gaps in knowledge and skills etc. (applied in the aggregate of tutoring relations for different students' clusters).

As concerns the information required for shaping the social and personal competencies (from the group of general competencies) that take into account the students' personal features, here we can partially make use of the information provided in professional standards in the Self-Development job description for each specialization [3]. In addition, in order to identify the personal features, there exists a great number of psychological tests, questionnaires, special websites etc. For instance, in the context of IES and web-IES [1, 2, 8–11, 14], the option of detecting approx. 20 personal qualities and their correlation with an individual tutoring model was implemented. The main problem here is to find and select the expert information that signals the degree, in which each particular competence is displayed for each of the personal features.

It is noteworthy that there is no general classification of competencies now, but the designation of professional and versatile competencies is a generally acceptable point of view. Further specification depends on the specific features of the profession, the traditions of the university that trains professionals in this domain and other particular features.

This paper is intended to review the methodical and technological experience in automated designing and use of tutoring IES and web-IES of competence-oriented models for future knowledge engineers ("system analyst" profession).

2 The Dynamic Designing of Competence-Oriented Models for Future Professionals Based on the Review of the Monitoring of Tutoring IES Students' Functioning Processes

Tutoring IES and web-IES developed in the laboratory of "Intelligent Systems and Technologies" of the Cybernetics Department of MEPhI have been pro-actively used since 2008 for automated support to basic courses and disciplines in such fields as

Applied Mathematics and Informatics and Software Engineering, in particular: Introduction in Intelligent Systems, Intelligent Dialog Systems, Dynamic Intelligent Systems, Designing the Knowledge-Based Cybernetic Systems, Modern Intelligent System Architectures, Intelligent Information Systems.

For all of these courses and disciplines, the applied ontologies were implemented and are dynamically supported using AT-TECHNOLOGY workbench basic tools. The ontologies jointly form the generalized ontology of Intelligent Systems and Technologies as the tutoring and methodic basis for training knowledge engineers. Significant methodological and technological experience was gained in automated maintenance of a significant number of individual models for the students in the above disciplines (over 2,500 models) and the appropriate tutoring models, the joint analysis of which enables forecasting so-called "perfect" model of a young professional, in particular, a systemic analyst (knowledge engineer).

The possibility of such forecast implementation is largely determined by the particular features of development and use of tutoring IES and web-IES related to automation of virtually all processes arising during tutoring and control of students' knowledge/skills. The entire information about the students, course/discipline topics, academic progress, students' monitoring results, individual recommendations based on the academic progress etc. are in the single environment and at any time available to the student and/or the academic progress supervisor, which is achieved by special monitoring tools for IELS students' functioning process.

Pursuant to [2, 10] and other papers, IES functioning is monitored from two angles. One of them is related to the role and part of tutoring IES in terms of tutoring management at the university, i.e. the use of IES for support of basic tutoring stages: holding of classes (lectures, workshops, laboratory work), holding of regular inspections, both during tutoring and at tutoring control points envisaged in the curricula of a certain course/discipline, as well as control efforts as part of credits and exams.

Another aspect is the review of a set of functional objectives typical of intelligent tutoring. Addressing the basic intelligent tutoring problems has been reviewed in various papers [2, 9–11] etc. many times; so, let's note that, in the context of summarized ontology of Intelligent Systems and Technologies and shaping the single ontological knowledge and skills space, we have managed to virtually implement the full set of functional objectives typical of the intelligent tutoring technology, namely [2, 9] etc.:

- *Individual planning* of the method to study the specific training course (specification of the personal tutoring trajectory/strategy based on the course/discipline ontologies, customized monitoring and identification of "gaps" in students' knowledge and skills, enhancement of individual tutoring with reference to the student's psychological profile, etc.);
- *Intelligent analysis* of solutions to training objectives (simulation of reasonings of the students who address training objectives of different type, in particular, using non-formalized techniques; identification of error types and reasons for their manifestations in knowledge and skills, instead of stating them; feedback via dynamic updates of the students' knowledge and skills; forecast of exam grades etc.);

- *Intelligent decision support* (use of the conventional expert system technology and tutoring IES technology for intelligent support at each stage of addressing tutoring tasks, including the expanded explanations of How? and What? type, selection of the solution options, prompt of the next solution stage etc.)

Thus, the monitoring of tutoring IES and web-IES functioning in this case is associated with "tracking" and review of all processes of shaping the student's individual model for each student for a particular discipline by identifying the current knowledge/skills level using web testing and other methods, as well as by shaping the psychological profile of the student's personality as an important component of the student's model.

It is noteworthy that, according to the problem-oriented methodology, the dynamic comparison of web testing findings with the respective fragment of applied course/discipline ontology forms the basis of the approach to designing the student's current competence-oriented model. The result is so-called "problem zones" [1, 2] in students' knowledge in individual sections/subsections and designing of the current competencies that jointly reflect the state of the student's model not only in terms of knowledge level but also by shaping the conceptual and technological link with the elicitation of the ability to solve certain types of educational unformalized objectives recommended in [23] or educational items on knowledge engineering, e.g. [16]. It is also necessary to constantly draft the lists of students (cohorts) with high and/or low knowledge/skills, conduct systemic statistical data processing and also generate current and final reports (lists) for departments and dean's offices.

The final term logs that reflect the students competence-oriented models contain comprehensive information on the students: their grades received during control efforts (exams, credits, tests) intended to elicit the level of knowledge and skills, the current professional competencies, information on the psychological testing passing, information

Final academic progress registers for Cb-221 Group, obtained with the assistance of IELS students in the Introduction to Intelligent Systems course

s/r #	Student's full name	Competence-oriented student model: Pb	Student's knowledge model (Ml[illegible]2017): Webinar results: Week 8 (28.03)	Week 15 (16.05)	Ml[illegible]2017 (Week 15): Topic/ sub-topic	Ratio	Student's abilities model (Ml[illegible]2017): Tests: Direct reasoning (4.04)	Reverse reasoning (4.04)	Semantic networks (11.04)	Frames (18.04)	Student's current competence level model: PK-1	PK-2	OK-5	OK-3	OK-4	Abstract	Additional credits	Test	Forecast	Exam
1	Aleksandrov Roman	+	22	67	Problem domain	0.0	48	53	88	45	0.61	0.52	0.51	0.48	0.62	4	0.25	passed	4	4
					Formalism selection for knowledge presentation	0.0														
					Types of semantic network relations	0.0														
					Concept of knowledge Neg-factors	1.0														
					Main knowledge extraction aspects	1.0														
					Systemic analysis of the problem domain for ES technology applicability	1.0														
					Analysis for suitability of ES application	0.38														
					Tool selection	0.2														
					Multilevel integration model	1.0														
					Knowledge acquisition models	0.5														
					Classification of knowledge acquisition methods	0.8														
					Standard development technology (ES) of the first generation	0.8														
					Concept of formal production system	0.167														
					Frame determination	0.08														
					Concept of frame prototype and frame copy	0.5														
2	Barvkin, Leonid	+	85	54	Classification of knowledge-based systems	1.0	100	98	76	80	0.55	0.52	0.53	0.58	0.60	3		passed	3	3
					Types of semantic network relations	0.56														
					Concept of knowledge Neg-factors	1.0														
					Knowledge acquisition phases	0.0														
					Analysis for ES applicability	1.0														
					Perfect expert identification criteria	0.3														
					Tool selection	0.75														
					Multilevel integration model	0.0														
					Classification of knowledge acquisition methods	0.0														
					Advantages and drawbacks of the key knowledge acquisition approaches	1.0														
					Standard development technology (ES) of the first generation	1.0														
					Frame determination	0.0														
					Concept of frame prototype and frame copy	0.8														
					Types of semantic network peaks	0.6														
					Control component	1.0														

Fig. 1. Example of final log for introduction into intelligent systems course

on independent work, the final grade forecast, and include the actual grade received in the exam (the logs are issued for all students trained in a particular course/discipline). An example of the final log fragment in the Introduction into Intelligent Systems discipline is shown in Fig. 1.

Analytical and statistical processing of tutoring IES application efficiency is critical for shaping the future professional's model. By introducing special parameters describing an individual student and a certain cohort (cluster) of students These parameters were derived expertly, based on the review of a rather representative data volume (approx. 2,000 students' models), and largely target the basic structure of the student's model [1, 2], the components of which are: student's knowledge model, student's skills model, psychological profile, competencies model and other components).

The experience suggests that the parameters (indicators) shaped as a result of [2] were the most sought of in terms of designing the competence-oriented models for future professionals.

- Review of "problem zones" for each student for particular courses/disciplines and their clusterization;
- Individual tutoring planning (typology and succession of training impacts; influence of training impacts on knowledge upgrading; search for the most efficient training impacts);
- Calculation of the correlation between the current knowledge and skills levels for the appropriate course/discipline topics;
- Account for the student's psychological profile (personal degree of achievement of target competencies for specific courses/disciplines etc.);
- Exam grade forecast based on academic progress (review of the reasoning when addressing particular educational and training tasks).

Besides, use a whole series of parameters for information processing for the entire students' cohort (group, flow, etc.) namely: aggregate analysis of "problem zones" for specific courses/disciplines and their clusterization; estimate and clusterization of individual tutoring plans for specific courses/subjects; exam session result forecast (the link between knowledge and skill level and exam grade by course; review and clusterization of students' psychological types, etc.)

Now let's look at practical examples of designing the "perfect" model of a graduate specialist in systemic analysis field (knowledge engineer) according to the base competencies of the current Federal State Educational Standard for Higher Professional Education in a greater detail.

3 Particular Features of Training Knowledge Engineers Based on Use of Tutoring IES

The successes of knowledge engineering in development of models and methods for knowledge transfer from different knowledge sources into a software, called the expert system (ES), and in a wider sense, the knowledge-based systems (KBS) [2, 13, 16, 23] resulted in a new occupation that requires not only professional competencies but also individual personal features. Thus, training of knowledge engineers implies not only gaining professional knowledge, skills and capacities in development (KBS) (ES) but also without regard to his or her psychological profile.

Let's provide some examples from the experience of practical application of tutoring IES and web-IES in the training process at MEPhI, with the emphasis on the technology for automated shaping of the competence-oriented model for a knowledge engineer, with reference to the set of training plans and the generalized ontology of Intelligent Systems and Technologies in Software Engineering training domain.

3.1 Shaping the Specialists' Professional Competencies

According to the Federal State Educational Standard 3+, the two following competencies are used as the base ones for training knowledge engineers:

- PK-1 is the formalization capacity in his or her subject area, with the view to the limitations on study methods in use;
- PK-2 is the readiness to use methods and instrumental means of study of professional business items

Achievement of these target competencies is facilitated by the common ontological space of knowledge and skills formed out of applied course/discipline ontologies of several tutoring IES and web-IES [2–7, 24]. It is noteworthy that the general competencies model that is the component of the basic ontology model in the shape of the semantic network [2], in the applied course/discipline ontologies, is represented as the hierarchy of the discipline/problem-oriented private competencies (with weight ratios) that reflect the methods of teaching some specific courses.

Table 1 shows the examples of specification of basic target competencies of PK-1 and PK-2 according to the ontology of the Introduction to Intelligent Systems course based on [23].

Let's briefly look at certain approaches to elicitation of individual professional competencies. Section 1 has already emphasized the particular features of elicitation of students' knowledge in control efforts (exams, tests, credits) by dynamic shaping of the student's current competence-oriented model that is based on the answers to special web tests and subsequent comparisons with the fragment of course/discipline ontology [2].

Now, we emphasize the problems of elicitation of the skills in application of theoretical knowledge in practical sessions. As the experience suggested, training of knowledge engineers implies learning the skills and capacities in solving practical tasks related to the ability to build the simplest situation models in the problem domain based on the "self-expert" principle, proceeding from products, frames and semantic networks [16].

Thus, when designing the tutoring IES, we created and tested during the training process at MEPhI and other universities the special software that implement the "manual" techniques of addressing non-formalized objectives (non-formalized problems), in particular, those shown in [23]. For instance, to elicit the competencies of PK1, PK11, PK12, PK13, PK14, PK15, PK16, etc. types as listed in Table 1, simulation of the reasoning of the students who solve four types of such non-formalized problems as [2, 4–7] is used: simulation of the strategies of direct/reverse reasoning in IES (PK13, PK14, PK15), simulation of simplest situations of the problem domain with the use of frames and semantic networks (PK12, PK13) etc.

Table 1. Examples of specification of target competencies PK-1 and PK-2

Designation	Full name
PK1	Ability to formalize his or her subject area, with the view to the limitations on study methods in use;
PK11	Know and be able to use the systemic analysis methods to assess whether the intelligent system technology is acceptable or not
PK12	Know and be able to select the knowledge presentation models for designing specific intelligent systems
PK13	Possess the skills in simulating reasoning and building-up modern problem solvers (output mediums) for intelligent systems
…	…
PK2	Readiness to use methods and instrumental means of study of professional business items
PK21	Know the main architectures of static, dynamic, integrated and hybrid intelligent systems and be able to design and develop them
PK22	Know the methods of designing knowledge bases for different problem/discipline areas
…	…

Figure 2 shows the fragment of the applied ontology, Introduction to Intelligent Systems, which comprises: Network Models of Knowledge Presentation, Frames, Frame Definition, Theoretical and Multiple Frame Description, Notion of Frame Prototype and Frame Copy, Homogeneous and Heterogeneous Frame Networks, LKP (language of knowledge presentation) based on frames, Release on Frames Such competencies as PK12 and PK13, which make part of the target competence PK1, are referred to this course/discipline ontology fragment.

In order to elicit the competencies of PK-2 type, the laboratory practicums and practical knowledge related to the instrumental and technological aspects of training knowledge engineers and those oriented on study of the designing technology (KBS) (ES) using the modern arsenal of instrumental tools [1, 2, 13, 23] are used.

Thus, using the Introduction to Intelligent Systems ontology and special means related to building up the student's current models, a certain set of professional requirements (criteria) to competencies of a future knowledge engineer is dynamically created. Table 2 contains example of some basic criteria for automated designing of a future specialist's professional competencies (with the recommended expert weights/ratings of each criterion under a 10-score scale) [2].

Now, let's look at the shaping of general cultural competencies and the psychological portrait of a future knowledge engineer.

3.2 Shaping the Psychological Profile of a Future Knowledge Engineer (in the Context of General Cultural Competencies)

As shown in [23], psychological aspect is critical for knowledge engineering, which is related to knowledge extraction processes, because this particular aspect determines if the knowledge engineer can successfully and efficiently liaise with the knowledge

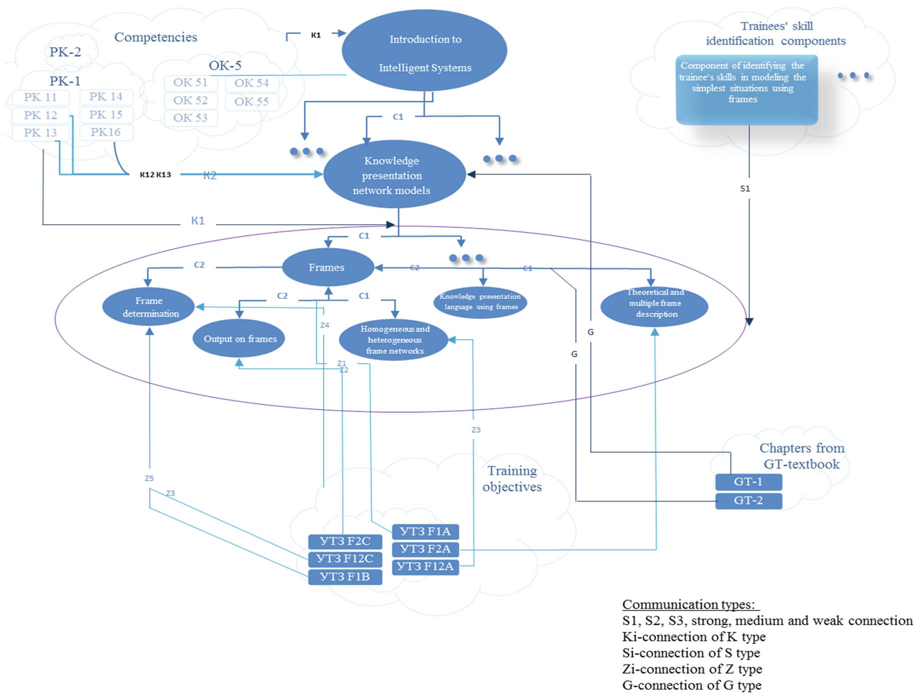

Fig. 2. «Introduction to Intelligent Systems» ontology fragment

source, the expert. In modern papers, e.g. [2, 15, 16, 23] etc., the suggestion is to take into account a series of personal features or their set as the psychological profile in determination of the so-called "perfect" couple, the knowledge engineer and the expert, to arrange for collective work in creation of the problem area model.

For these purposes, almost two dozen of various author texts are currently used in tutoring IES and web-IES, and the most appropriate test configuration for psychological tests of students depending on the identified competence type is determined using the psychological test generator.

In terms of the Federal State Education Standard 3+, to shape a knowledge engineer's psychological profile, the following target competencies are the most suitable out of general cultural competencies:

- OK-3, the ability to communicate verbally and in writing in Russian and foreign languages to solve the tasks of inter-personal and inter-cultural communications;
- OK-4, the ability to work as part of a team, by perceiving social, ethnic, confessional and cultural differences with tolerance;
- OK-5, ability to self-manage and self-educate.

However, the use of automated methods for elucidation of the above OK-3, OK-4 and OK-5 competencies is an understudied problem now. There are virtually no papers on establishing the explicit connections between individual personal features of a student's psychological profile and the general cultural competencies. Therefore, as

Table 2. Basic requirements to a future knowledge engineer

s/r #	Requirements	Rating weight
1. Do you have	Broad general scientific training	
	Acquaintance with the reviewing, annotation and other text processing methods	3
	Mastery of quick reading skills	3
	Knowledge of textological methods of deriving knowledge	3
2. Do you know….	Acquaintance with the reviewing, annotation and other text processing methods	3
3. Do you master…	Mastery of quick reading skills	1
4. Do you know…	Knowledge of textological methods of deriving knowledge	9
5. Do you have….	Basic training in information sources	
	Qualified knowledge of the methods of knowledge acquisition from different knowledge sources	8–9
	Qualified knowledge of models and methods of knowledge presentation in information sources	8–9
	Qualified knowledge of knowledge processing methods in information sources	8–9
	Qualified knowledge of the systemic analysis basics	8–9
	Mastery of basic information structuring methods	8–9
	Cluster analysis	8–9
	Hierarchical clusterization	8–9
	Designing weighted situations	8–9
	Ranking the selection trees	8–9
	Repertoire grid analysis	8–9
	Possession of KBS (ES) development methods	8–9
	Qualified knowledge of instrumental tools of KBS (ES) designing	8–9
	Holding the practical computer skills, one or several programming languages	8–9
6. Do you master…	Qualified knowledge of the methods of knowledge acquisition from different knowledge sources	
	Communications methods	7
	Textological methods	5
	Methods of knowledge acquisition from the database	6
7. Do you master…	Qualified knowledge of models and methods of knowledge presentation in information sources	
	Logical models	5
	Inferential	1
	Inductive	1
	Other	1
	Heuristic models	8

(*continued*)

Table 2. (*continued*)

s/r #	Requirements	Rating weight
	Network	8
	Frames	7
	Semantic networks	5
	Other	3
	Production	8
	Other	3
3. Do you master…	Qualified knowledge of knowledge processing methods in information sources	
	Direct or reverse conclusion	8
	Analogy/precedent based conclusion	5
	Other	3
9. Do you know….	Qualified knowledge of the systemic analysis basics	5
10. Do you master…	Mastery of basic information structuring methods	
	Multiple scaling	5
	Hierarchical clusterization	3
	Designing weighted situations	3
	Conclusion tree ranking	5
	Repertoire grid analysis	5
	Other	3
11. Are you experienced in….	Possession of KBS (ES) development methodologies (stages, life cycle, etc.)	7
	Prototyping strategy mastery	8
12. Are you experienced in…	Qualified knowledge of instrumental tools of KBS (ES) designing	9
13. Do you master…	Holding the practical computer skills, one or several programming languages	8
14. Do you know….	Knowledge of cognitive psychology elements	
	Methods of representing notions and processes in human memory	5
	Main thinking principles (logic, associativity)	5
	Thinking activation methods	5

part of tutoring IES and web IES, a cycle of studies intended to specify, in particular, the competencies of OK-4, because the experience related to analysis and clusterization of the students' psychological types has been gained here, and psychological tests are carried out, with the view to the personal degree of achievement of target professional competence of a knowledge engineer.

4 Conclusion

Thus, the methodical and technological experience gained in training professionals in Applied Mathematics and Informatics and Software Engineering in the domain of automated designing using tutoring IES and web-IES of competence-oriented models of knowledge engineers enable to promptly and efficiently review, adjust (based on the cutting-edge innovations in the professional area) and forecast the level and quality of the graduate professionals' cohort. Such approach does not lay down the new foundations only in relations with employers and potential customers only, but also enables planning of the target training of specialists in various fields among undergraduates.

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Learning Strategies and Future of Educational Technology

Advancing Performance Assessment for Aviation Training

Beth F. Wheeler Atkinson[1], Mitchell J. Tindall[1(✉)], John P. Killilea[1], and Emily C. Anania[2]

[1] Naval Air Warfare Center Training Systems Division, Orlando, FL, USA
{beth.atkinson,mitchell.tindall, john.killilea}@navy.mil
[2] Don Selvy Enterprises, Lexington Park, MD, USA
naniael@my.erau.edu

Abstract. A major goal of human factors interventions in aviation environments is to increase performance without sacrificing safety. The performance assessment state-of-the-practice within aviation training relies heavily on instructor observations and performance checklists or gradesheets. While these tools quantify trainee performance, they focus on outcomes as opposed to the processes (i.e., behaviors and cognitions) that led to a good or bad performance. Theoretical guidance and technological advances offer opportunities to improve the effectiveness and efficiency of instructor feedback by increasing the availability of diagnostic feedback [1]. Specifically, construct validation research indicates that multiple criteria and methods for measuring performance are necessary to provide and accurate picture of performance [2, 3]. Increasing the focus of observer-based grade sheets to account for process-oriented and higher order cognitive skills encourages feedback discussions to address diagnostic details. Additionally, improvements in system processing and computing power can offset human-in-the-loop data analysis with automated capabilities. These system-based measures standardize outcome assessments that minimize human biases and errors [4, 5]. For these reasons, the use of system-based measures to complement instructor-observed assessments provides a more comprehensive understanding of performance. This approach increases reliability of performance evaluations thereby improving determinations of proficiency by relying on quantitative assessments, vice participation or quantities of exposure. This presentation will discuss ongoing efforts to develop and transition tools to address these gaps in current aviation performance assessment capabilities. The goal is to capture observer gradesheets and automated performance measures that reflect individual and team performance on tactical tasks that can be archived for long range data analyses. In addition to presenting the system architecture, the presentation will include a discussion of future directions such as archival systems leveraging data science and the need for increased standardization in performance measurement implementation.

Keywords: Performance assessment · Measurement validation
Training effectiveness · Observer-based metrics
Automated system-based metrics

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1 Introduction

The growing interest for data analytics within the Department of Defense provides a prime opportunity to leverage existing data sources for human performance assessment. Specifically, the use of quantitative performance data for determining skill levels of trainees supports diagnostic feedback, targeted remediation, and identification of opportunities to accelerate or tailor training to student learning progress. Limitations exist in the current state of the practice that minimizes these prospects. Human performance assessment within aviation training predominately relies on subjective instructor observations. A review of gradesheets often identifies a lack of objective, outcome-based assessments of aircrew performance critical to operational mission success. Further, communities often use data only for a single post-event debrief with no integrated storage system for additional analysis. These limitations create challenges for assessing force-wide training trends to accurately gauge tactical and technical proficiency. However, using technology to collect, capture, and store relevant data sets, enables the measurement of force-wide tactical proficiency and the subsequent implementation of focused training solutions in a resource constrained environment.

2 Motivation

The state-of-the-practice in U.S. Navy aviation training performance assessment is a labor intensive process that relies on instructors who are simultaneously tasked with setting up the scenario, running the scenario, role playing (using radios and chat screens), providing feedback and grading/assessing the aircrew. These scenarios can last up to four hours not including the prebrief and debrief. Furthermore, the performance assessment gradesheets are paper-based making it less likely trends in aircrew performance will be analyzed and used for subsequent instruction. There is less focus on actual aircrew proficiency and more on scenario exposure. Aircrews only need to have flown a mission to qualify for deployment. This is not to imply that proficiency is not a focus but that a qualifications-based assessment often lacks the detail necessary for a comprehensive assessment that can lead to a more efficient aircrew. Performance is a multi-faceted construct and if instructors are to provide comprehensive, detailed and accurate feedback to aircrews on each facet of their performance, it is important to advance our performance assessment systems.

Simulation-based training environments provide excellent opportunities to develop tools with the potential to increase the detail, comprehensiveness and accuracy of performance assessment, while also reducing workload on the instructor. Specifically, data derived from simulators can be used to automatically assess certain facets of performance that were traditionally either ignored or assessed by the highly preoccupied instructor. It is important to note that not every facet of performance can be assessed using this approach, as certain facets will still require the observation and judgment of an instructor. However, automatically grading facets has the indirect benefit of alleviating instructor workload, allowing them to focus on the areas that require their attention. The resulting system should produce a more detailed, comprehensive and accurate assessment for more efficient aircrews and training systems.

3 Improving the Validity of Aircrew Assessments

Observer-Based Measures of Performance. Observer-based measures of performance (MOPs) typically pertain to the behavioral and cognitive processes that lead to a performance outcome (e.g., mission success, aircrew safety, efficiency). An example of a process that would lead to mission success for an aircrew would be effective crew resource management (CRM) – communication and coordination of the aircrew. Such processes are highly nuanced and require human observation and intellect to be adequately assessed. However, recent advances in simulation technology coupled with requirements to provide data for the purposes of performance assessment create unique opportunities to assess outcomes and the processes that usually require observation. Much of an airman's job is utilizing some form of mission control station (MCS) to inform, direct, pursue, attack, etc. Their inputs into these control stations can be captured and used for analysis and provide insight into the crew's thinking and actions. Essentially, these user inputs are behaviors that are indicative of performance and subsequently related to an outcome. While outcomes can be evaluated through observation, they are typically rated using other means such as mission success versus failure, number of accidents, and timeliness. Since outcomes are easily rated using other means, observation is best suited for assessing the behavior and thought processes that led to these and other outcomes. For example, if an aircrew track and correctly classified a target their mission would be considered a success. One of the greatest strengths of observation-based process-oriented MOPs is they show trainees how to be successful by providing the detail needed to improve subsequent performance [1]. That is, they help trainees focus on how to be successful. However, observational-based process-oriented assessment is not without its flaws. Despite their best efforts, human judges will always rate performance with a degree of error. This error may be the result of bias, lack of attentional resources, or inconsistent frames-of-reference. Fortunately, where observation is weak outcome-oriented assessments tend to be strong and this complimentary nature of the two approaches produces a more comprehensive assessment that inherently allows for validation.

System-Based Measures of Performance. System-based measures of performance typically tell us what happened or the outcome of a process (e.g., mission succeeded) but not how it happened. Relying on systems to help make these judgements eliminates the error contributed by biases, attentional resources and frame-of-reference. However, system-based measures only tell us what happened, but not how it happened. For example, an aircrew may successfully identify a target quickly without employing all the tactics needed to do so because the target was conspicuous. Essentially, this aircrew was successful due to luck instead of an underlying proficiency. Another aircrew that employs every learned training tactic correctly to identify a target may not succeed because the target's counter tactics made it invisible to the crew's instrumentation. If we relied solely on system-based measures of performance we might conclude the first aircrew was more proficient than the second. Thus, we would reinforce their behavior and potentially encourage bad habits. It is for this reason we would not advocate a complete departure from observer-based MOPs but instead a complimentary approach to using both. Additionally, the two approaches could be used to validate individual measure facets. For example, since aircrews the employ effective CRM tactics make fewer accidents an observer-based rating of CRM should relate to a system-based rating of accident frequency. The correlation between these MOPs is evidence that they're indeed measuring what is intended (Table 1).

Table 1. Benefits and limitations of system-based and observer-based measures of performance.

Type	Process	Outcome	Detailed feedback	Unbiased	No training	Timely
Observer	x	x	x			
System		x		x	x	x

4 Progressing Toward a New Culture of Aircrew Assessment

Military domains are inherently dynamic. Often the goal of any Military or their specific platforms is the enhancement of current or the advancement of future capabilities. This environment results in a constant cycle starting with research and development, acquisition, integration and implementation of new tactics, techniques, procedures (TTPs) or technologies. Data pertaining to platforms and crew performance are absolutely necessary to assess the return on investment (ROI) of novel approaches and innovations. While much of the data needed to assess the effect of R&D efforts on mission success, efficiency, and resource allocation is and has been collected for decades, the accessibility and ease with which that data can be analyzed is a different matter. Additionally, not all data that is produced and collected is useful for answering important questions throughout the acquisition lifecycle. For example, questions pertaining to the proficiency with which a particular squadron performs Anti-Submarine Warfare (ASW) missions rely on qualifications data. Qualifications data provide information about the number of specific ASW missions an aircrew performed but less detail about the effectiveness with which the aircrew performed those missions. For leadership and instructors, greater variance in data regarding aircrew proficiency is incredibly useful for a breadth of activities. Increased variance can help validate the effectiveness of a new TTP or technology. Leaders concerned with identifying the "right" aircrew for a specific mission could use the data to optimize their chances of mission success. Instructors and the training community can use the data to identify gaps in training and appropriately plan remediation strategies.

The state-of-the-practice has accentuated qualifications and observational-based gradesheets to answer many of the questions outlined above. Observational-based gradesheets offer increased variability above and beyond what qualifications provide. This variance results in a focus on the behavioral and/or cognitive processes that led to successful or unsuccessful mission outcomes. This increased variance is important as it enables instructors and stakeholders to differentiate between multiple levels of proficiency and subsequently determine what things separate the most from the least proficient aircrews. While observer-based data increases variance it is important to reiterate that it still contains error in the form of biases and known limitations in human perception, attention and retention. Therefore, stake-holders of this data are discouraged to rely on it solely for informing decisions.

As previously mentioned, advances in technology have created new opportunities for easing and improving the process and practice of human performance measurement. This is especially true in military domains that rely more and more on computer simulations to train the warfighter. The training simulators produce vast amounts of data as they operate. Some of this data pertains to timing of significant events, training inputs and ground truth. Software programs can be developed that automatically extract and combine these data pieces to provide useful information about an individual's or crew's performance across multiple facets (e.g., accuracy, timeliness, efficiency). Unlike observer-based measures of performance these automated or system-based measures of performance are largely outcomes (e.g., accurate attack) and not processes (e.g., crew-coordination). As previously stated, many platforms today require individuals and crews to perform most of their duties through some form of MCS. Their inputs into an MCS can provide useful information about their thinking prior to performing an action. This is an important point of emphasis as robust and comprehensive performance measurement systems should contain information both about the behavioral and thought processes that led to an outcome and the outcome of processes.

Above we outlined the importance of data analytics for a variety of functions. The implications of this approach are that vast amounts of data will be collected and stored in a centralized location. Unfortunately, collection and storage of data is only half of the battle. In military domains these data sets can be immense and overwhelming. When multiple stakeholders (e.g., Chief Naval Officer, Commodores, Naval Field Officers, and Instructors) have interest in various pieces of this data it can be a huge undertaking ensuring they can easily access and analyze the data that matters to them. Leveraging existing software database technologies to build graphic user interfaces that allow for easy access and analytics is the next logical step in this process. That is, you can build a comprehensive system for performance measurement that combines observer-based metrics and automated MOPs but it will not matter if end-users cannot easily use that data to inform opinions and decisions.

Integration of Automated, System-Based Measures of Performance. Other efforts have focused on the integration of observations into automated performance measures. A current Navy project is aimed at supplementing current observer-based feedback with extensive automated performance measures in the context of maritime patrol reconnaissance. This is done in such a way that all information is in the same repository, empowering decision makers to leverage multiple data streams when determining proficiency levels. The repository allows for information to be stored and leveraged for immediate training feedback, or at a later date in order to understand current proficiencies and comprehend and track trends in readiness and proficiency for aircrews.

Currently, observer reports are written and filed away, making some information largely inaccessible. However, as discussed earlier, automated performance metrics do not allow for a complete picture of trainee performance, as they are largely outcome-based. In order to integrate process-oriented feedback, observer reports are necessary. This complete integration, stored in a cloud-based repository allows for easily accessible data which is a much easier starting point for decision making, compared to data distributed in multiple places and in multiple modalities. Further work in this domain focuses on the need to ensure that new training technologies implement such standards, allowing all training to store information in such a way that tactical and technical proficiency data can be effectively utilized.

Development of Data Repository and Analysis Tools. With the development of new data repositories, data analysis and visualization must also be considered. There are many concerns which must be addressed. First and foremost, data analysis is often effortful and requires a knowledgeable eye to deliver meaningful results. Those who make high-level decisions may not always have the know-how to utilize data analysis software, and as such, automated performance measures must have some capability to automate analyses. Currently in development is a system which will not only address this concern, but also strives to make performing analyses intuitive to the front-end user.

In addition, data trends are constantly changing for an environment such as the military, as tactics and techniques change. These data often lack a clear beginning or end, and have the potential to grow to an immense magnitude, which offers rich sources of data and limitless potential, but can also further complicate analyses. Big data is a source of interest in many domains, and current projects aim to gauge the best way to perform analyses on constantly changing big data sets to an end which makes these analyses both easy and useful for a variety of users.

5 Conclusions and Future Directions

Advances in new hardware and software technology are creating opportunities to advance the science of human performance measurement. The ability to easily retrieve, integrate and analyze data relevant to human performance directly from simulation-based training systems has the potential to alleviate many of the limitations of observer-based measures. The implications of these advancements are aircrews that operate more safely and efficiently and are more tactically proficient. In addition, these new tools can provide useful data to decision makers up and down the chain-of-command and do so in real-time. The aforementioned advancements to performance measurement systems within the military can ultimately result in a significant advancement to the warfighter.

However, these military-based simulation training environments are highly dynamic creating new obstacles with every opportunity. Data derived from these environments are nothing like experimental design with a specific beginning and end. Experimental data sets are contained and each variable collected is operationalized by the designer of the study. Similar rigor in research methodology will ensure the validity of data in highly dynamic environments where data is constantly streaming but this rigor is difficult to achieve. With continuous streaming data sets some variables can quickly become obsolete while new variables are added to the equation. To parse the effects of aircrew proficiency versus advances in technology and tactics on mission performance, tools need to be developed that check the validity of existing variables and identify when new variables need to be added and properly operationalized. The Navy has begun addressing this issue by leveraging work in industry and knowledge in academia. Using the Small Business Technology Transfer (STTR) program the Navy has challenged industry to develop software-based analytic tools while working with academia to ensure adherence to the latest data science models. Though in its first phase of development Techniques to Adjust Computational Trends Involving Changing Data (TACTIC-D) is intended to begin addressing the many challenges associated with the management and analytics of large streaming data sets in highly dynamic environments. Specifically, this topic calls for the development of technology based on statistical or computational methods to assist in the continued tracking of training performance and proficiency trends as underlying tactical data changes.

It is understandable for researchers and decisions makers to get excited about the possibilities and opportunities that result from system-based automated MOPs. Human performance measurement is an inherently difficult science that relies on flawed human judgement for data. Furthermore, large samples of data overtime that are necessary for analytical power are rare. Many of the challenges traditionally associated with human performance measurement can be overcome by leveraging new technology. Nevertheless, it is crucial that the science keeps up with the technology considering the implications of these capabilities in military domains have vital consequences.

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Assessing the Role of Behavioral Markers in Adaptive Learning for Emergency Medical Services

Kimberly Stowers[1(✉)], Lisa Brady[1], Youjeong Huh[1], and Robert E. Wray[2]

[1] The University of Alabama, PO Box 870225, Tuscaloosa, AL 35487, USA
kstowers@cba.ua.edu, {llbrady,yhuh1}@crimson.ua.edu
[2] Soar Technology, Inc., 3600 Green Court Suite 600, Ann Arbor, MI 48105, USA
wray@soartech.com

Abstract. Tools for adaptive learning are on the rise, resulting in the creation and implementation of increasingly intelligent tutoring systems. These systems can be applied in a variety of contexts, including civilian, military, and emergency operations. Such systems may also include the capability to adapt to learner needs based on performance or behavioral input. However, the use of such adaptation may vary in its success depending on the domain it is applied to. This paper examines the potential utility of adaptive tutoring for educating Emergency Medical Service (EMS) workers. We examine two complementary approaches that can be used to drive adaptation: performance-based and behavior-based adaptive learning models in intelligent tutoring. We then discuss implications of implementing such learning models for intelligent tutoring in EMS. Next, we outline ongoing research as a use case for the validation of different adaptive learning models. Finally, we discuss expected impacts of this line of research, including the expansion of adaptive tutoring to other domains related to EMS.

Keywords: Intelligent tutoring · Training design · Adaptive training

1 Introduction

The world of work is changing. A 2016 Pew Research Center [1] survey found that 54% of workers believe it will be essential for them to develop new job skills throughout their work life to keep up with changes in the workplace. Such beliefs are well-founded, as many are forecasting that the rapid proliferation and advancement of technology will cause many changes in the employment landscape across a broad range of occupations and industries, (e.g., [2]). Certain fields, such as emergency medicine, are increasingly faced with a number of changes related to advanced technology and equipment, modified regulations, and updated safety procedures. Because the field is always changing, emergency personnel must constantly be re-educated to not only learn the changes but also implement them into their routines.

Although having students receive individualized instructor assistance during any learning process is ideal, the reality is that these resources rarely exist. One solution, however, is the development and utilization of intelligent tutors (i.e., computer-based

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artificial agents [3]). Intelligent tutors may not only approach the effectiveness of human teachers, but also be able to customize and personalize instruction to achieve efficient and effective learning outcomes for all students. The purpose of this paper is to examine the utility of intelligent tutoring for Emergency Medical Services (EMS). We begin by reviewing the state of the science of adaptive learning—including performance-based and behavioral-based adaptive learning models—as well as their propensity for use in intelligent tutoring for EMS. We then present ongoing research as a case for the validation of related adaptive learning models. Finally, we discuss the impacts that can be expected as a result of designing and implementing adaptive tutors for EMS and across a variety of occupations.

2 Adaptive Learning for Emergency Medical Services

Adaptive learning, in which a learning environment adapts to the abilities, needs, and preferences of individual learners, has been identified as a "Grand Challenge" for 21st century research and engineering [4]. The benefits of adaptive learning environments include more efficient learning [3], improved attention and motivation [5], the development of less rigid and more flexible decision making (i.e., adaptive expertise, [6]), and improved transfer of learning to settings in which learned knowledge is used and applied [7–9]. Adaptive learning has application for more pervasive and less costly training, as opposed to training that has traditionally been delivered by human instructors in classes with modest student-to-teacher ratios. Human instruction is very valuable and —in some cases—can be adapted to individual learners in a meaningful way. However, technological adaptive methods offer an opportunity to deliver effective training tailored to a greater degree and available to a greater number of students. This, in turn, can enable a single human instructor to train many more students with a greater degree of individualization.

In the context of EMS training, adaptive learning may lead to greater training and performance outcomes, especially if the tutor in question utilizes scenario-based learning methods (e.g., [10]) wherein the content to be learned is presented in the context of the real-world environment [11, 12]. Indeed, research has shown that EMS workers' performance in a simulated field environment matches their success in completing standardized EMS tests [13]. Additionally, results from a prior study assessing the utility of a serious game for training EMS nurses suggested that adaptation of training to varying levels of expertise might be an improvement over a static (i.e., non-adaptive) virtual training environment [14]. What remains unknown, however, is how best to apply adaptive methods to an EMS training environment.

2.1 Approaches to Adaptive Learning

Adaptation to a learner usually requires a model of the learner that is frequently updated as a learner progresses through a curriculum [15]. The targeting of adaptive techniques, such as scaffolding [16] and competency matching [17, 18] depends on the accuracy (and, to some degree, precision) of the learner model. When the model better reflects the learner's actual knowledge, skills, and attitudes at any point during the learning, the targeting of the adaptive method to the learner generally improves [18].

Creating a complete and accurate learner model is difficult, however, and several approaches exist. Traditionally, adaptive learner models were created from formal and informal assessments within the learning environment [15, 19–21]. Over time, adaptive learning methods have evolved to include other triggers for adaptation, including "markers" of human behavior and biology related to cognitive states in the learner. Next, we discuss these two approaches for creating adaptive learning systems. Specifically, we look at the utility of performance markers and behavioral markers for adapting EMS training to individual learner needs.

Performance Markers. Performance-based adaptation focuses on altering learning content according to the learner's performance over time. This may include giving immediate feedback to the learner (e.g., [19]), redirecting the learner to content that should be reviewed to improve or maximize performance (e.g., [22]), or choosing what content is most appropriate to present next as learning progresses [23]. Additionally, the learner may be able to repeat or review content as desired. Regardless of the particular approach, to maintain ongoing adaptiveness, the tutor should track learner performance over time. Thus, several performance markers have been identified to aid in this process.

Performance markers can be thought of broadly as markers that represent the knowledge, skills, abilities, and other relevant characteristics (KSAOs) of the learner [24]. By linking KSAOs to learning or training objectives, it becomes possible to identify domain-specific performance markers. For example, what KSAOs should the learner demonstrate throughout training to indicate s/he is meeting a particular learning objective?

Linking performance markers to learning objectives provides ample opportunity to create an adaptive tutor that tracks performance effectively in EMS training. In the domain of EMS, learning objectives vary according to the specific position of interest. For example, the National Standard Curriculum for Emergency Medical Technician (EMT) training divides learning objectives into three categories–cognitive, affective, and psychomotor–and three levels–knowledge, application, and problem-solving [25]. Identifying performance markers that represent some or all of these categories and levels may prove useful to the adaptation of the training. However, for computer-based training of real-world skills (such as patient triage), it is often difficult to develop accurate performance-based markers that represent true operational knowledge. Additionally, the method of assessment can be confounding as well. As a simple example, when a learner is asked to answer a multiple-choice question, a correct answer could be indicative of actual knowledge and ability, or it could be due to other factors (lucky guess, lack of time pressure, access to other resources, etc.) Rather than use performance-based markers alone, these limitations suggest the need for complementary functions that can mitigate some of these limitations.

Behavioral Markers. In addition to estimating learner capability from formal and informal assessment within the environment, researchers have explored many behavioral, physiological, and even neurological indicators or "markers" that can provide additional context for improving the dynamic assessment of the learner. The purpose of such markers is to identify learners' cognitive states and select learning strategies based on that information [26].

Learner states of interest may include arousal, attention, and other cognitive states or processes that impact learning behaviors [27, 28]. In particular, understanding the dynamic patterns of learner arousal allows the identification of dynamic adaptation targeted to the identified arousal states [29]. To that end, markers that have been used to track learner arousal/attention in learning environments include behavioral sensors (e.g., posture, expressions, mouse movements), physiological sensors (e.g., galvanic skin response [GSR]), and neurological sensors (e.g., electroencephalography [EEG]; and see [30]).

Tracking learner states may be particularly useful for guiding learner participation in EMS training. Indeed, since a training program is only as successful as its ability to engage learners [31], implementing a system that can track cognitive states and respond to those states in a way that increases engagement and learning is well-advised. Prior research examining attitudes of EMS students toward computer-based training showed that preferences for such training were moderate at best, suggesting that lack of engagement might dampen the students' attitudes [32]. Additionally, because some aspects of successful EMS performance includes the ability to handle pressure and stress, a learning environment that could appropriately raise learner arousal (while not overwhelming the learner) would be beneficial for deeper learning. As such, adaptation that uses behavioral markers to facilitate engagement and personalization beyond a traditional learning environment may be warranted.

2.2 Selecting Markers for EMS Training

In the domain of EMS training, a combination of both performance and behavioral markers may be most promising for creating an adaptive learning system that is both accurate and practical. As stated above, the selection of performance markers should be linked to the objectives in question. A straightforward performance marker may simply be the "correctness" of the learner's response. However, the marker should be further contextualized according to the materials being learned. For example, contextualizing a marker to fit the National Standard Curriculum for EMT [25] would involve marking the response according to the category (i.e., cognitive, affective, psychomotor) and level (i.e., knowledge, application, problem-solving) of questions answered. This would then allow the learning model to take into account whether the learner is doing better in certain categories than others. Similar approaches can be taken for other EMS curricula.

EMS training can be further personalized through the implementation of meaningful behavioral markers. However, most behavioral markers today require sensors that are not commonly available on the hardware available for typical computer-based learning: a laptop or a tablet. This can make the implementation of behavioral markers quite costly. In addition to the expense of developing tutors that implement various behavioral markers, supplying the hardware necessary–especially in learning environments that may not otherwise have them–may be infeasible or unrealistic.

Thus, it is important to consider ways in which behavioral markers can be implemented at a low cost and with low intrusion to available learning environments. One such marker that can be readily implemented in a computer-based environment for a fairly low cost with little disruption is mouse-tracking. The utility of mouse-tracking lies in its ability to infer learner focus during a decision-making process. For example, in the case of a learner viewing a multiple-choice question, mouse-tracking can provide real-time evolution of the decision making process the learner is engaging in, including which responses s/he is considering most heavily [33]. For EMS, there may be further use in tracking mouse movement as learners view specific images in which they are asked to identify emergency-related factors.

To that end, combining mouse-tracking with contextualized performance tracking can provide insight to the learner's evolution of knowledge and skills during a learning session, as well as the process underlying that evolution. Furthermore, combining these approaches can both contextualize their use as well as provide further validation for their utility in adaptive learning.

3 Ongoing and Future Work

To explore recommendations discussed throughout this paper, we have developed an adaptive learning system for EMS which has the capability to exploit both performance markers and behavioral markers. The basic learning environment has been used to present computer-based learning and scenario-based practice in a web-delivered system [34, 35]. We have extended the environment to perform adaptation based on markers derived from mouse-tracking [36] to complement the adaptive performance based markers built into the tool [34].

A previously developed analysis provided insight to the role and impact of markers for a well-designed curriculum for EMS [37]. Curriculum units have since been developed for "Scene Size-Up," a required curriculum component used in Emergency Medical Technician (EMT) training [25]. Scene size-up regards the initial assessment of the scene by the EMT on arrival and spans all of the learning goals outlined for the curriculum above. Using these units, a study has been designed to identify the impacts of performance-based adaptation on learning and whether (and to what extent) there is benefit for using behavioral markers in addition to performance markers in this adaptive EMT training.

The study, currently underway, compares the results of learning in a scene size-up presented in three different ways: two adaptive units, and a unit presented in a non-adaptive or fixed sequence. The three variations in the adaptive tutor being tested can be described as such:

- Condition 1: Non-adaptive. The instructional unit is presented in a fixed sequence. Learners receive generalized feedback to every response (both correct and incorrect responses).
- Condition 2: Adaptive based on performance (only). The instructional unit is presented in a fixed sequence that includes immediate, adaptive feedback in response to learner questions. Learners receive feedback specific to their response (correct,

incorrect) and targeted to the specific choices the learner made. Highly specific feedback and remediation is provided for "close" responses; more general, conceptual feedback is given for responses that are (conceptually) far away from the target response. Such feedback design is consistent with guidance for the design of feedback delivery in learning systems [38]. Learner knowledge and skill is estimated and updated as learning progresses.
- Condition 3: Adaptive based on performance and markers. The instructional unit is presented in a variable sequence. The sequence and feedback are dynamically constructed/chosen based on a combination of direct learner observation (as above) and behavioral markers—specifically indicators captured via mouse-tracking. Only two types of sequence variation are introduced in this study: repeating a prior question and skipping a question.

The primary performance marker tracked in this study is response selection (i.e., correctness of selected response) which is mapped to the learner model. As stated above, mouse-tracking is the behavioral input. We have developed the following markers for this study based on the mouse tracking input [36]:

- Confidence: An assessment of the learner's confidence in a selection or choice. The marker is derived from a combination of movement patterns and dwell times on screen items.
- Secondary choice: An evaluation of learner choices that attempts to identify if the learner considered another choice (or subset of all choices) more heavily than the other choices.
- Likely target: For item selection tasks, this marker predicts a learner's likely mouse target in advance of reaching that target, reducing the chance that mouse overs that occur during movement to a target are treated as targets.

These markers are used to make adaptive selections of content, feedback, and remediation in condition 3. For example, a learner that selects the correct choice with low estimated confidence may be given some feedback and remediation following that choice while a high confidence learner is allowed to proceed immediately to the next item. Similarly, a learner that selects a "far target" choice with high confidence is immediately asked to try again without any feedback under the assumption that this choice may be due to lack of engagement than lack of knowledge.

The primary outcome that will be assessed in this study is knowledge gain, quantified as difference scores between pre- and post-tests given to participants. The study will be conducted with university participant population(s), which will allow for a sufficient sample to assess the utility of each tutoring approach. This will provide a strong foundation for future studies to pursue further validation with incoming EMT and other EMS worker populations to indicate their success with its use.

4 Expected Impacts

Although the primary focus of the present chapter is examining the utility of adaptive tutoring for educating EMS workers, furthering research in this area can be expected to have broader impacts than those discussed thus far. Specifically, these impacts include: (1) improving the state of the science on adaptive tutoring; (2) providing optimal and affordable EMS training; and (3) extending the use of adaptive training from EMS to other occupations.

4.1 Improving the State of the Science on Adaptive Tutoring

As discussed prior, adaptive learning has been identified as a "Grand Challenge" for 21st century research and engineering [4]. Improved adaptive learning has applications for more pervasive and less costly training in a wide variety of domains, from classroom education to on-the-job training. For example, research has been conducted in the context of training soldiers in the U.S. Army using an adaptive tutor to make one-to-one tutoring possible (e.g., [26]). However, challenges still remain regarding the cost of authoring effective adaptive tutors, as well as discovering adaptive tutoring technologies that can more accurately perceive a learner's state and progress [26]. To that end, testing the utility of various behavioral markers in combination with performance markers can aid in designing more precise learner models for adaptive tutoring systems.

4.2 Providing Optimal and Affordable EMS Training

One of the challenges EMS practitioners are currently facing is a number of changes on the horizon in emergency medicine, such as modified regulations and procedures. The constantly changing nature of EMS protocols requires all staff in various levels to be continuously re-educated. One of the most effective solutions to this need is to design adaptive tutors that move beyond simply identifying individual errors and advance toward understanding the process and needs involved in knowledge acquisition. Adaptive tutors can provide fine-tuned, individualized training, making it easier to educate people with varying levels of expertise. In addition, from a practical standpoint, utilizing low-cost, low-intrusion behavioral markers will allow EMS personnel to receive a unique, adaptive training that is less costly and more convenient than neuro-cognitive markers.

4.3 Extending the Use of Adaptive Tutoring to Other Occupations

Although EMS personnel receive training that is specific to their role, there are a number of occupations in which professionals (e.g., police officers, fitness trainers, and lifeguards) are required to learn similar skills—such as those related to CPR and First Aid. Designing adaptive tutors for EMS can thus aid in designing specialized learner models for occupations across a variety of industries. Although additional research is needed to validate the use of markers and learning models that are relevant to on-the-job training in other domains, the implementation of adaptive tutoring within training contexts is likely to increase dramatically in the near future. Due to imminent changes within the workforce, employees within a variety of industries will need to acquire additional knowledge, skills, and abilities. Thus, designing specific adaptive tutoring platforms that respond to the training needs within each industry could provide a solution to this widespread need.

5 Conclusion

The workplace continues to evolve rapidly as a result of technological, societal, and political changes, making our discussion on the development of intelligent tutors timely and essential. Although current and future employees acknowledge the need to constantly learn and apply new skills to perform well in their role, a lack of time and resources makes this process difficult, if not impossible. With the increasing use of mainstream adaptive learning tools, however, intelligent tutoring may provide a solution. In this paper, we evaluated the science of performance-based and behavioral-based markers used for adaptive learning, discussed the utility of creating an adaptive intelligent tutor that incorporates meaningful behavioral and performance markers of learning to train EMS personnel, and provided an example of ongoing research within the specific domain of EMT. Our examination of strategies involved in creating adaptive tutors provides an example of these tutors can be used within a specialized and high-risk occupation. However, as the evolving world of work begins to generate related changes within training environments across a variety of industries, the use of adaptive tutors may be not only helpful, but necessary.

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Name Tags and Pipes: Assessing the Role of Metaphors in Students' Early Exposure to Computer Programming Using Emoticoding

Angelos Barmpoutis(✉) and Kim Huynh

Digital Worlds Institute, University of Florida, Gainesville, FL 32611, USA
angelos@digitalworlds.ufl.edu, huynhtina123@ufl.edu

Abstract. This paper presents a case study for assessing the effect of emoticoding during the students' first encounter with text-based coding interfaces, in which period a student could have a deeply disappointing experience that may lead to "blank page trauma" as well as negative attitude towards the subject. A prototype metaphor-based source code editor was developed using novel human-computer interaction mechanics based on the concept of emoticon-like scripting. Similarly to the use of shortcuts for typing emoticons in social media, visual or textual replacements appear in the proposed text editor when the user types complete valid tokens from a given programming language. Appropriate metaphors can be used in the design of the token replacements so that they are appealing to a particular age, gender, or cultural groups of users. Quantitative analysis of data from 5th-grade students (n = 40) shows that metaphor-based emoticoding improves significantly the students' performance in terms of syntax recall when they transition from block- to text-based programming in comparison to transitioning without emoticoding.

Keywords: Computer science education · Computer programming
Source code editors · STEM education · Emoticoding

1 Introduction

It is known in computer science education that learning to program can be a challenging task for beginners of all ages [1] and may lead to "blank page trauma" [2]. Among the several methods and teaching instruments that have been developed to address this issue, the three most notable types of tools for learning computer programming are Tangible User Interfaces (TUI), Graphical User Interfaces (GUI, also known as visual or block-based coding environments), and Text Editing Interfaces (TEI) for source-code editing. TUIs are experiential tools for early computer education (Fig. 1) that build connections with real world skills and experiences [3, 4]. GUIs are the virtual equivalents of TUIs and can improve students' understanding especially in middle learning stages, as they have greater flexibility in content (Alice [5], Scratch [5, 6], Tynker [7], iVProg [8], Greenfoot [5], etc.).

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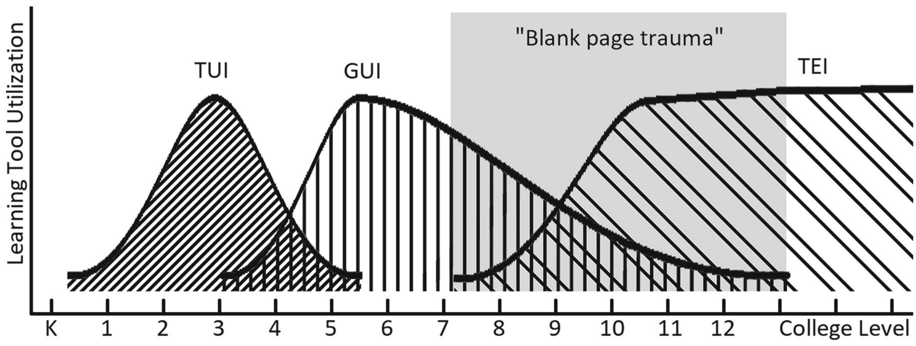

Fig. 1. Illustration of the utilization of learning tools across school levels. The most probable age for experiencing "blank page trauma" is when students transition to TEI (in gray box).

Contrary to the "toy"-looking interface of TUI and GUI tools, TEIs offer a text-editing interface that resembles professional integrated development environments [9, 10]. Several studies indicate that the key advantage of TEIs is that they do not underestimate the detail and complexity of more comprehensive programming languages [11, 12], while TUIs and GUIs have limited utility in teaching advanced concepts [6]. Furthermore, students learning to program in GUIs may show certain habits that are contrary to the basic programming recommendations [13].

However, transitioning to TEIs can be a challenging task for a beginner [1, 2], since they provide a significantly larger number of degrees of freedom to the students compared to GUIs. A simple deviation from the syntactic rules produces compilation errors, which may not be easy to be detected and resolved by beginners. Such an early disappointing and frustrating experience caused by repetitive errors may lead to negative attitude towards the subject. A deeply disappointing experience is one of the many different factors that can cause emotional and psychological trauma, which can affect sustained and focused attention, though selective attention, which is used when processing sensory memories into short-term memories, is not affected [14, 15].

In order to bridge the gap between GUIs and TEIs, a novel method is presented and assessed in this paper, which is a hybrid method that combines the visual effectiveness of GUIs with the coding complexity of TEIs using a real programming language. More specifically, it maintains the detail and capabilities of professional programming languages and at the same time adds a human-readable layer on top of the typed code using age-appropriate visual or textual replacements. Our research is based on the hypothesis that a smooth transition between GUIs and TEIs can improve students' success during their first encounter with TEI environments, and subsequently increase the probability of developing a positive attitude towards the subject. The hypothesis was tested on 40 5^{th}-grade students who used the proposed TEI environment, which is a text-editor with emoticon-like text replacement capabilities that allows a novel coding interaction dubbed "Emoticoding" [16].

2 Method

The use of metaphors in education is a common and well-established practice that allows students to build strong associations between a learning topic and familiar concepts or experiences from a properly chosen metaphor. In computer science education, metaphors have been used in the majority of the aforementioned learning methods. TUIs are based on direct associations between computer programming concepts and tangible hands-on experiences from familiar gaming interfaces such as building blocks or jigsaw puzzles. Similar metaphors are used in GUIs that offer virtual interfaces for connecting components (blocks) such as puzzle-like connections or directed wires that connect the output of a block with the input of another one.

However, metaphors have not been significantly utilized within text editing environments, which creates a significant disconnect between GUIs and TEIs despite their adjacency as steps in the learning path of computer programming. In this paper we propose the use of metaphors such as jigsaw puzzle pieces as part of a mechanism that interactively replaces individual programming tokens typed in the text editor using the framework of emoticoding [16] (see Fig. 2).

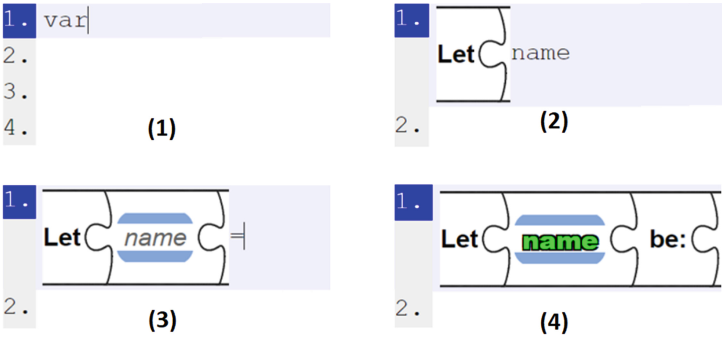

Fig. 2. The prototype editor in four instances during the typing of the JavaScript code: var name = … (1) During the typing of a new token, the typed code appears as in a conventional editor. (2) As soon as a complete valid token is typed, it is interactively being replaced by a visual metaphor. (3) The user can continue typing more tokens or erase existing ones in an intuitive emoticon-like typing. (4) Example of three tokens in the proposed text editor with replacements designed for K-12 students using metaphors such as puzzle pieces, name tags, and others.

The method presented in this section is based on the theory of brain-activating text replacements that was introduced in [17] and has been shown to improve the performance of college-level beginner programmers in terms of syntax recall and logic comprehension. For the purposes of the present study, a prototype source-code editor was developed that has novel human-computer interaction elements that deviate from the conventional text editing interfaces. More specifically, the re-designed interface of the text editor has the following features:

Block Sequence. The body of the text consists of rectangular areas that are arranged sequentially along each line of the typed text.

Dual Mode Interaction. Each block can be either in edit mode or rigid mode. During edit mode the user can type text, while in rigid mode the block is decorated with a graphic or text that replaces the user-typed input. At most one block is in edit mode at a given time.

Active Tokenization. As the user types computer code, an active tokenization algorithm splits the text into individual programming tokens, which turn into blocks that are decorated with a corresponding graphic or text description (Figs. 2 and 3). Because of the resemblance of this interaction with the use of shortcuts for typing emoticons in social media, we name this coding process "emoticoding".

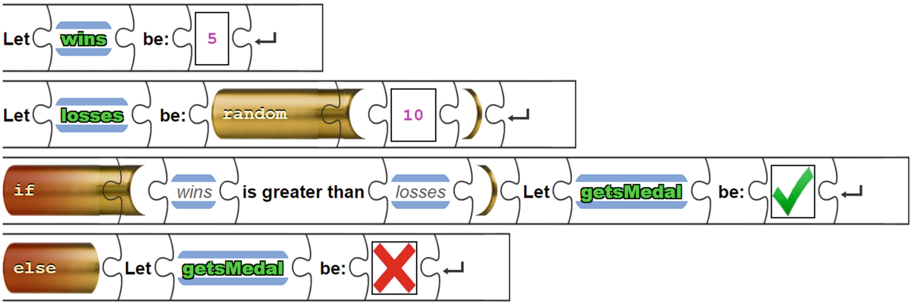

Fig. 3. An example of a 4-line program in JavaScript visualized using the metaphors designed for this study. Each token was composed by typing a valid token in JavaScript syntax.

Compatibility with Conventional Text Editing. The user can still perform all standard text editing tasks, such as erasing blocks with backspace, selecting, copying, pasting blocks and their underlying computer code, etc.

Group Representation. Finally, several consecutive blocks can be replaced by a higher-level block if they represent a self-contained programming entity that was identified through active tokenization. For example all the blocks contained within "/*" and "*/" (comment delimiters) can be grouped together by one larger block that replaces the entire typed comment. Examples of other self-contained elements are functions, classes, etc.

The text replacements that appear when a block is in rigid mode can be designed for specific user profiles based on their age, gender, language/ethnicity, etc. Figures 2 and 3 show various examples of replacements that were designed for K-12 students using various metaphors such as puzzle pieces for separating individual tokens, name tags for variable names, and English words/phrases such as "Let" and "be:" for the tokens "var" and "=" respectively. A complete set of more than 90 text replacements was designed for the purposed of this study.

3 Case Study

The proposed editor was implemented as a web application [16] with an active tokenizer for JavaScript and tested by 40 5th-grade students from Gainesville, Florida who volunteered to participate in this study. To enroll in this study the student should have no prior experience in coding, which was determined in the enrollment questionnaire that was filled by all the participants. In order to assess the effectiveness of the proposed metaphor-based method as a tool for smooth transition to TEI environments, we followed a curriculum that involved GUIs for early exposure of the students to computer programming, which was then followed by transition to TEIs.

More specifically, before the study the students were exposed to computer programming using a GUI (Tynker [7]) for a period of 10 weeks following a curriculum from "Hour of Code" (hourofcode.com) for 1 h/week. After the end of this training period, the students were split into two same-size groups, and each group transitioned to a different TEI environment. The students of each of these two groups were exposed to the same basic programming syntax such as variable declaration and conditionals for approximately 45 min. During the same time the students of each group practiced using their assigned TEI; group A used the proposed TEI with metaphor-based emoticoding; group B used a conventional TEI (source code editor) without emoticoding.

At the end of the study all students had to complete the same programming assignment in JavaScript based on the material that was covered in the study. More specifically, the students were asked to declare a few variables (such as "score" and "medals" with assigned values 5 and 0), and use a few conditional statements (such as "if the value of score is equal to 5 then set medals to 1", etc.), with complexity similar to the example shown in Fig. 3. The students had to complete the assignment with pen and paper in order to test if they could recall the syntax and logic of the programming language without the assistance of the compiler or the proposed metaphor-based token replacements.

4 Experimental Results

The students' solutions to the programming assignments were quantitatively evaluated for accuracy using four different metrics: (1) The submission had no errors (i.e. can be successfully compiled), (2) The variable declarations had no errors, (3) The conditionals had no errors, (4) There were no other errors. Note that these are four independent metrics with binary value, which were uniformly applied to all students.

The first column in Fig. 4 shows the percentage of the students who completed the assignment without errors (metric 1). According to this metric, the students who transitioned to the proposed metaphor-based TEI performed better compared to the students who used a conventional source code editor. More specifically, the use of metaphor-based emoticoding increased the success of the students by a factor of 7.5, i.e. 68% vs. 9%.

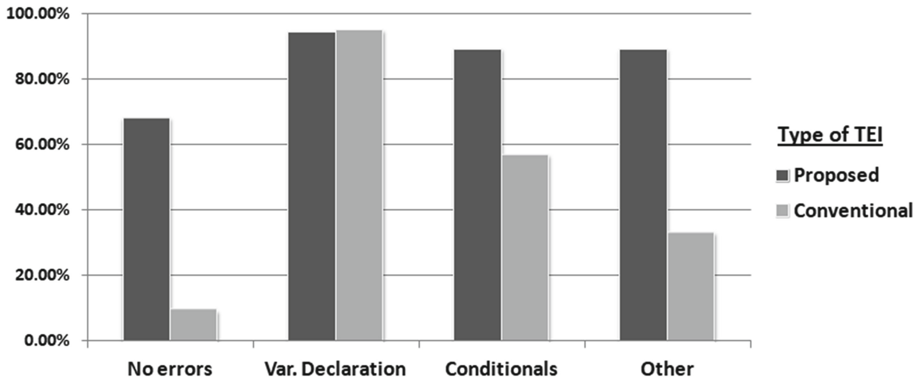

Fig. 4. The percentage of successful students for each type of TEI using the four predefined evaluation metrics.

The remaining columns in Fig. 4 show the detailed percentages of the students who performed successfully in metrics 2, 3, and 4. Overall, the percentages indicate that the use of metaphor-based emoticoding yields equal (metric 2) or better results (metrics 3 and 4) compared to conventional TEIs. More specifically, the percentage of success was increased by a factor of 1.6 (from 57% to 89%) with regard to the use of conditionals, and by 2.7 (i.e. from 33% to 89%) with regard to other syntactical structures respectively. The latter category included all other observed syntactical errors, such as missing semi-colons at the end of individual commands, unbalanced parentheses or braces, etc. Additionally, the following observations were made:

The students who transitioned to the proposed metaphor-based TEI typed more examples of variable declarations and conditionals during the allotted 45 min. of training. The responsiveness of the text editor with emoticoding increased the level of student engagement, who wanted to play more with the JavaScript source code, compared to the conventional source code editor.

Emoticoding helped students identify incorrect programming syntax by means of English syntactic errors in the phrases composed from the token replacements. For example, a correctly defined condition will read "if score is equal to 5…" contrary to the grammatically incorrect "if score be: 5…" caused by the erroneous use of the symbol "=" instead of "==", which correspond to "be:" and "is equal to" respectively.

Students who used emoticoding acquired additional knowledge from what was covered in the tutorial by simply interacting with the system. For example, the erroneous use of a space within a variable name produces two tokens (emoticon blocks) instead of one variable name (one block) which is the goal. After this observation, they corrected the error by removing the space, which indicated that they learned that spaces are not allowed within variable names.

Only in one student's submission there was confusion between the elements of Java-Script with the text-replacements of emoticoding. For example, instead of the keyword "var" the student typed "Let", which was the corresponding token replacement shown in the proposed metaphor-based emoticoding editor.

5 Discussion and Future Directions

The aforementioned findings indicate that the proposed method improves the performance of 5th-grade students, which is in agreement with the results obtained from a previous study on non-Computer Science college-level students [17]. The findings from these two studies indicate that overall emoticoding facilitates the learning of computer programming across ages, from elementary school to college, an argument that should be verified through long-term studies in the future.

A key difference between GUIs and the proposed TEI-based environment is that the former constitutes a new programming language (a visual or block language), while the latter facilitates the learning of an existing programming language. As a result, an important benefit from using the proposed method is that the student acquires a skill set that is directly applicable in many areas (game, web, app development), i.e. the knowledge of a professional programming language (in this study JavaScript).

This distinction makes it difficult, or better irrelevant to compare these two methods in terms of syntax recall (for example compare how many students know the difference between "=" and "==" after using these two methods). The different goals and objectives between GUIs and TEIs make them two distinct but equally important steps in a sequence of steps that leads beginners to coding.

In this sequence, the discontinuity between GUIs and TEIs due to their differences in complexity, degrees of freedom, and human-computer interaction can be smoothed by the use of emoticoding in TEIs. More specifically, the results from this study suggest that by introducing metaphor-based emoticoding to source code editors, the students' success during their first encounter of TEIs is significantly increased by a notable factor of 7.5. The students who transitioned from GUI to the proposed text editor demonstrated superior knowledge of programming (in JavaScript) compared to the students who transitioned from GUI to a conventional source code editor. These findings support the hypothesis expressed earlier.

Furthermore, if "blank page trauma" is related in some degree to the disappointing experience that a beginner may have, the proposed method can be reasonably considered a helpful tool for reducing this problem. Subsequently, the proposed method can increase the probability of a student developing a positive attitude towards the subject, an argument that will also be tested more thoroughly in a long-term study in the future.

Finally, various different sets of visual or textual replacements can be designed with focus on specific target populations that might benefit significantly from this tool, such as minority students, female students, and other groups. More specifically, emoticoding can be used as a culturally responsive teaching method that can appeal to the specific interests of target populations within a specific spatiotemporal context. This can be implemented by using visual replacements with metaphors from athletics, music, nature, fantasy, comics, urban life, science, and others that could be appealing to different individuals or groups of individuals. Such metaphors can increase the effectiveness of emoticoding for these populations and subsequently serve as a catalyst for gaining essential technology-oriented skills that can be applied to all STEM areas in general as it was recently shown in [18].

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Extending the Sentence Verification Technique to Tables and Node-Link Diagrams

Mark A. Livingston(✉), Derek Brock, Tucker Maney, and Dennis Perzanowski

Naval Research Laboratory, 4555 Overlook Ave SW, Washington, DC 20735, USA
{mark.livingston, derek.brock, tucker.maney, dennis.perzanowski}@nrl.navy.mil

Abstract. In addition to prose, situation reports used by various organizations often present supporting information in "visual" formats that pose unique challenges for assessing readers' comprehension. Two of the more common information categories seen in these reports are text-based tables and node-link diagrams. To better understand what readers attend to in these formats, we adapted a proven method for assessing prose comprehension, known as the Sentence Verification Technique (SVT), to these ancillary materials and conducted an exploratory reading study with format, aspects of the SVT, and contextual information as independent variables. Except for tables, error rates were comparatively uniform. Assessments of prose were significantly faster than assessments of diagrammatic information, which in turn were significantly faster than table assessments. The latter also took longer when posed without contextual details. We conclude that the SVT can be successfully adapted for information in ancillary formats and discuss further research issues for this endeavor.

Keywords: Reading comprehension · Sentence Verification Technique (SVT) Text tables · Node-link diagrams · Quantitative evaluation

1 Introduction

A situation report (SITREP) is a standardized information or status report that is commonly used by military forces [1] and international organizations [2, 3] for operational purposes. SITREPs present much of their information in narrative or prose form, but many also make use of ancillary tables and diagrams. The display format and/or non-linguistic elements of these latter modes of information generally require readers to employ correspondingly different perceptual and cognitive skills [4].

To gain a better sense of what makes tabular and diagrammatically depicted information easier or harder to read, understand, and retain, we extended a proven procedure for measuring prose comprehension, known as the Sentence Verification Technique (SVT) [5], to these "visual" information formats. We then applied this work to a simulated military SITREP written for non-specialists and conducted an exploratory human performance study to evaluate the merits of this approach and

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examine the comparative effects of different ways of “quoting” information from a larger visual context.

2 Related Work

The SVT ([5]; all quotes in this paragraph are taken from this reference) was introduced as a method for measuring a reader’s comprehension of a prose passage or message. It is based in part on the premise that “the memorial representation of this comprehended message is thought to be in a form which preserves the meaning of the message but not its surface structure.” This premise motivates various text alterations for querying comprehension. The SVT procedure entails first presenting a passage to read, giving the reader as much time as needed to peruse and understand the information, and then removing the written material. Subsequently, readers are given a series of sentences based on the written source and are asked to verify whether each sentence is “old” information (i.e., information that was stated in what they read) or “new” information (information that disagrees with or was otherwise not represented in the passage). The SVT defines four types of queries that authors of an SVT test must derive from individual sentences in the prose passage. An *original* query is simply a verbatim copy of any sentence in the reading passage; clearly, this is “old” information. A *paraphrase* query is a sentence “in which as many words as possible were changed without altering the meaning or the syntactical structure of the original sentence.” This also constitutes “old” information. Conversely, a *meaning change* query is a sentence “in which one word in the original sentence was altered such that the meaning of the sentence was changed.” This change would thus make the sentence “new” information. A *distractor* query is “consistent with the general theme of the passage,” but unrelated to the content of any original sentence (making it “new” information). Furthermore, a distractor should have “the same length, syntactical structure, and difficulty level as the original sentence.”

The SVT paradigm has already been adapted to measure comprehension in other information display settings. Royer [6] describes its use with speech, which follows naturally for listening to sententially structured spoken material. In our own work, the SVT was recruited to assess listeners’ comprehension of rate-accelerated speech. Brock et al. [7, 8] found that the content of digitally accelerated speech from a single talker was comprehended at similar rates to non-accelerated speech and significantly better than that of concurrent talkers. Our present extension of the SVT to tables and node-link diagrams represents an initial attempt to adapt it to media in which propositions and cues are conveyed through means other than sentences. Royer and Cunningham [9] weighed the potential of this idea against the challenge of creating appropriate visual passages and queries.

Mosenthal and Kirsch [10] developed a methodology that scores document readability in part by including the complexity of the structure of tables and graphs. For example, a table with multiple columns is harder to read than a single column list. Intersected lists (tables that require row and column headers), nested lists (multiple layers of headers), and the number of labels a table requires further increase the difficulty of reading a document and, so, its readability score. Equivalencies between data charts (pie chart, bar graph, line graph, and time line) and various table properties were also defined, but empirical and/or applied evaluations of their method were not discussed. Kosslyn [11] provided guidelines and examples of organizing and labeling charts and node-link diagrams. Kosslyn's work was derived from principles and findings in cognitive psychology, but no formal assessment of difficulty or studies of the guidelines were reported.

3 Testing Comprehension of Tabular and Diagrammatic Information

3.1 Fictional Scenario

The non-specialist SITREP composed for this study outlines a fictional military scenario that delineates an area of responsibility (AOR) assigned to a Marine Corps battalion. The scenario includes the battalion's mission, routine assignments, the duties of its four companies, and a range of local tactical, institutional, and socio-political concerns. The document has an extended prose narrative, a geographical map of the AOR, two informational tables, and a relational node-link diagram. The first table textually outlines the geography, key institutions, and other matters of interest in the AOR, with separate entries for urban and rural areas. The second table similarly lists operational locations, assignments, and duties for the companies in the battalion. The diagram depicts important demographic and political entities in the AOR and the state of their activities and relationship(s) to each other.

3.2 Adapting Sentence Verification Technique Queries

One of our goals was to use the SVT to study readers' comparative understanding of the prose, table, and diagrammatic portions of the SITREP. To adapt SVT queries to tables and diagrams we defined equivalent structural units in each format to a sentence of prose. This information was visually "quoted" and an alternative *paraphrase*, *meaning change*, and *distractor* was composed for each *original* quote per the SVT definitions for queries. Table "sentences" corresponded to single table entries (i.e., a cell) and only the cell text was altered. Diagram "sentences" entailed two nodes and an edge, the latter being the "verb," and both node labels and edge types could be altered depending on the query. To preserve the relevant coordinating information in each format, unaltered row and column headers and the diagram's legend were always respectively included in these queries.

Another aspect of tables and diagrams we felt warranted consideration is the cueing function visual layout may have in readers' coded understanding of information in these formats (cf., [12]). To study whether removing different degrees of this cue would affect performance, three levels of this factor, which we refer to as "contextual display format" (or more simply as "context") were devised. These levels are designated as *with context*, *minus context*, and *context free*. Figure 1a shows a diagram used in our study's training material along with examples of how our context definitions apply to diagram queries. Queries shown *with context* include grayed-out versions of the complete diagram (Fig. 1b), which preserves the full layout, the information being queried, and the legend. However, grayed-out text is replaced by ellipses and grayed-out edges are replaced by undirected dotted lines. The next level (Fig. 1c), designated *minus context*, retains only the original layout of what is being queried and removes the remainder of the source diagram. *Context free* queries (Fig. 1d) are redrawn more compactly to show the information being queried as a straightforward assertion, independent of its original visual context. As a comparative baseline for these three contextual levels of visual queries, we also derived—as a fourth level of "context"—an equivalent set of linguistic queries for each visual quote (i.e., a lexical sentence composed to convey the visually quoted portion of a table or diagram and a corresponding *paraphrase*, *meaning change*, and *distractor* derived from this sentence). Respectively, these queries incorporated either a table cell's relevant coordinating information (its row and column headers) or the relevant definitional information from the diagram's legend and/or its title. Not to be confused with "prose queries"—queries specifically derived from quotes of the prose portion of the SITREP that are also included in the study (see below)—we refer to these lexical characterizations of queries derived from visually quoted tabular and diagrammatic information in the SITREP as *written* queries. Our study's design choices are not the only way to form queries consistent with the SVT rubric; for example, in our "table queries" and "diagram queries" respectively, the relevant headers or the legend could also have been altered per the SVT's rules for query types. We leave these alternatives for future work.

3.3 User Study

With our Institutional Review Board's approval, we recruited 32 volunteers (21 male, 11 female) from the scientific and clerical staff at our laboratory. Participants ranged in age from 23 to 68, with a mean of 42 and median of 38. Three were non-native speakers, but each had at least 25 years of experience speaking and writing English.

After giving their informed consent and completing a pre-study questionnaire on relevant skills, participants worked through an interactive training session that introduced the SVT and our extensions of it to visual quotes from tables and diagrams. The three levels of visual context shown in Fig. 1 (*with context*, *minus context*, and *context free*) and the corresponding *written* queries used as a comparative baseline for visual queries were also introduced at this point. Next, participants read a short prose passage on international energy use that included an informational table and a relational diagram. Then they practiced for the study by verifying a comprehensive series of queries on this material. Explanatory feedback was provided after each response, but only for these practice queries. The formal portion of the study with the simulated SITREP followed. Participants then completed a post-study questionnaire and were debriefed.

The design of the formal study was as follows. Twenty-four informational quotes were selected from the SITREP: eight were sentences drawn from its prose material, eight (in total) were cells taken equally from its two tables, and eight were relationships depicted in its node-link diagram; no quotes were drawn from the map of the AOR. Per the SVT, these quotes formed a base set of *original* queries for each mode of information (i.e., prose, table, and diagram). Next, a corresponding *paraphrase*, *meaning change*, and *distractor* query was developed for each quote. Each of the resulting 32 table and 32 diagram queries was then rendered in the four contextual display formats: *with context*, *minus context*, *context free*, and *written*. The study thus entailed 32 possible prose queries, 128 possible table queries, and 128 possible diagram queries. Participants verified only one query for each the 24 quotes (eight prose, eight table, and eight diagram queries), so coverage of the full set of 288 queries was accomplished through a counterbalanced set of 16 manipulations. Each manipulation was completed by two participants and featured two instances of each type of query in each information mode and, for table and diagram queries, two instances of each level of contextual display.

(a)

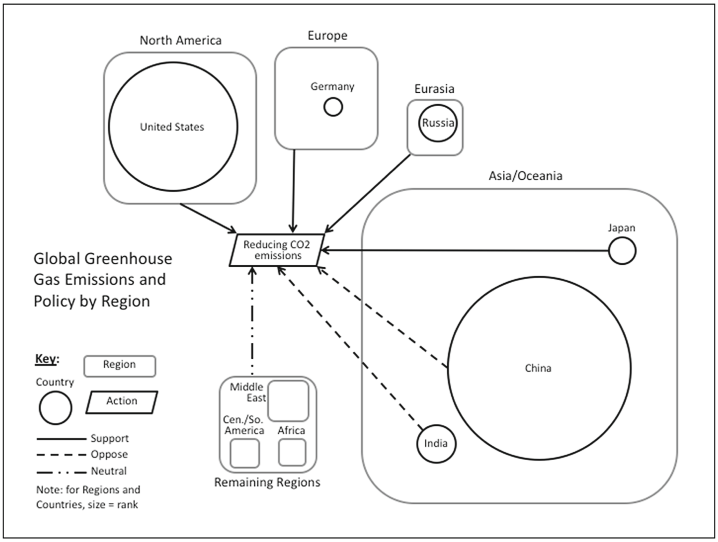
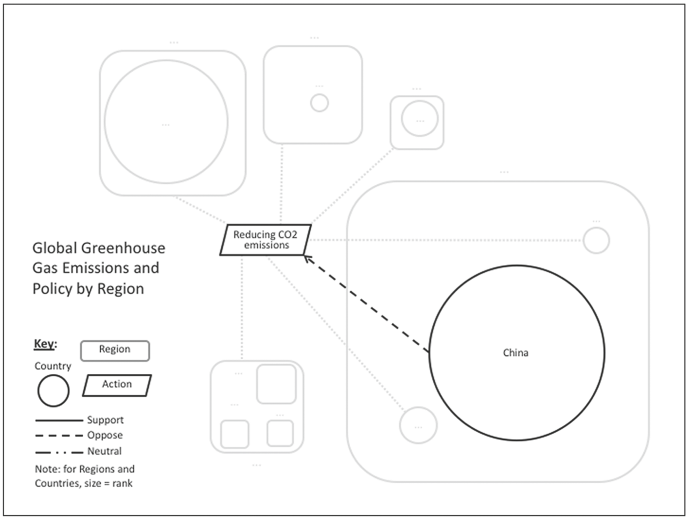
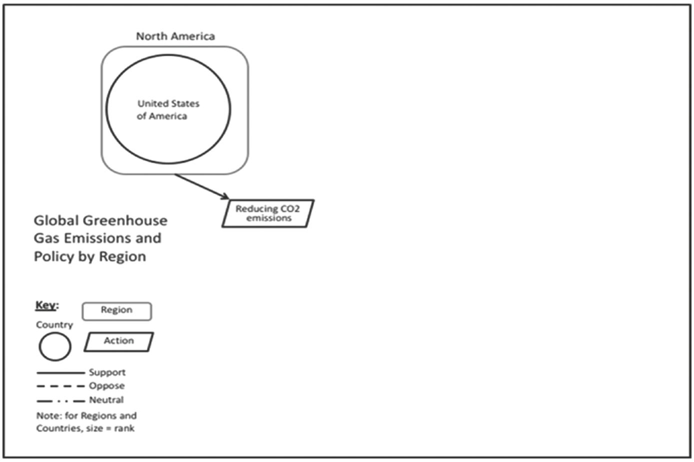


Fig. 1. Practice diagram included in the study's training materials and successive SVT query types respectively cast in the study's four levels of contextual display. (a) The entire diagram as it appeared in the information passage. (b) An *original* query shown *with context*. Note that the diagram's layout and its legend and title are preserved, but unrelated nodes and edges are grayed-out and extraneous labels are changed to ellipses. (c) A *paraphrase* query ("United States of America" paraphrases "United States") shown *minus context.* Again (cf. (b)), the source diagram's layout, legend, and title are preserved, but unrelated nodes, edges, and labels are removed. (d) A *meaning change* query (use of the "Support" edge contradicts the "Neutral" edge appearing in the source diagram (a)) shown *context free.* The legend and title are preserved but the source diagram's layout is dropped and the nodes and edges forming the query are compactly repositioned. (e) A *distractor* query (Korea is not in the source diagram (a)) in *written* form. The query is verbally derived from the information domain shown in the diagram. Although the diagram's coordinating legend and title are shown, unmodified, in visual queries (b), (c), and (d) —regardless of each query's level of "contextual formatting"—the title is the only relevant coordinating information referenced in *written* query (e). Bounding boxes shown in this figure indicate the extent of the source, (a), and each visual query, (b), (c), and (d), participants saw but were not shown in the study.

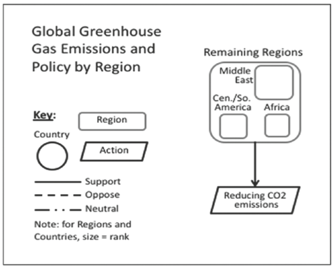
(b)



(c)



(d)



(e) Korea's Greenhouse Gas Emissions Policy is the same as Japan.

Fig. 1. (*continued*)

4 Results

Two of the study's chief concerns were: whether our SVT extensions would work for tables and diagrams and, if so, whether the SVT query types would yield reasonable levels of performance. Most participants completed the study within an hour; three participants took longer, primarily spending additional time on the practice material and reading the SITREP. Further details of our analysis (and design) can be found in [13].

Using repeated-measures analysis of variance (ANOVA), we conducted a series of analyses and focused on differences in error and response time due to three factors: SVT query type, source material mode, and contextual display format ("context"). We report test statistics, Greenhouse-Geisser corrections to *p*-values, generalized effect size $\left(\eta^2_G\right)$, and post-hoc paired t-tests. $\alpha = 0.05$ is used for significance; values of *p* between 0.05 and 0.10 are noted as "marginally significant." Analyses of response time were conducted only with correct responses.

In the course of the analysis, we identified an intended *meaning change* corresponding to one of the prose quotes as erroneously formed. All eight participants who saw this query assessed it as "old" information. A careful review of the SITREP revealed that the *meaning change* arguably paraphrased a conflation of information in one of the tables. Consequently, this query was removed from the analysis.

4.1 Effect of SVT Query Type

Over the full SITREP, there was no main effect of SVT query type (*original*, *paraphrase*, *meaning change*, *distractor*) on error rate $F(3,93) = 1.188$, $p = 0.317$, $\eta^2_G = 0.023$. There was a marginally significant main effect of SVT query type on the response time $F(3,93) = 2.622$, $p = 0.077$, $\eta^2_G = 0.022$. The mean response time for *distractor* queries was lower than for *paraphrase* queries, $t(31) = 2.392$, $p = 0.023$, for *original* queries, $t(31) = 2.372$, $p = 0.024$, and for *meaning change* queries, $t(31) = 2.378$, $p = 0.024$. Tables 1 and 2 respectively report mean error rate and mean response time by query type and source.

Table 1. Error rate by query and source material modes.

	Original	Paraphrase	Meaning change	Distractor	Total
Prose	0.094	0.141	0.143	0.172	0.137
Tables	0.141	0.141	0.266	0.234	0.195
Diagram	0.125	0.156	0.156	0.063	0.125
All sources	0.120	0.146	0.190	0.156	0.153

Table 2. Response times (sec.) by query and source material modes.

	Original	Paraphrase	Meaning change	Distractor	Total
Prose	8.87	8.30	8.86	8.81	8.71
Tables	13.67	13.92	13.43	12.68	13.44
Diagram	11.53	11.78	11.43	09.25	10.96
All sources	11.31	11.33	11.23	10.14	11.00

4.2 Effect of Source Material Mode

There was a significant main effect of the mode of SITREP source material on error rate F(2,62) = 3.207, $p = 0.049$, $\eta^2_G = 0.044$. For these data (see Table 1), error on queries about the diagram was significantly lower than on queries about the tables, t (31) = 2.561, $p = 0.016$. Error on queries about the SITREP's prose material was lower than on queries about its tables by a marginally significant amount, t (31) = 1.797, $p = 0.082$.

There was also a significant main effect of source material on response time for correct responses F(2,62) = 25.501, $p < 0.001$, $\eta^2_G = 0.169$. All pairwise differences for these data (see Table 2) passed a *t*-test. Participants were significantly faster on prose queries than on diagram queries, t(31) = 3.333, $p = 0.002$; they were in turn significantly faster on diagram queries than on table queries, t(31) = 3.843, $p = 0.001$. (Participants were significantly faster on prose queries than on table queries, t (31) = 7.067, $p < 0.001$.) Figure 2 plots group means for error and response time by source material mode.

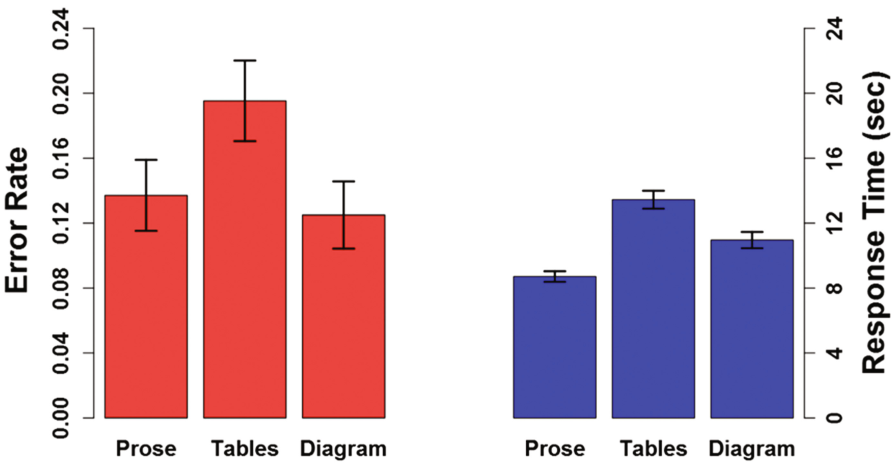


Fig. 2. Group means for error rate (left, red) and response time (right, blue) by source. There were significant main effects on error rate and response time. In pairwise comparisons of error, only the difference between diagram and table queries was significant. All pairwise comparisons of response time were significant. Error bars show the standard error of the mean.

Characteristic differences between these data and patterns seen in earlier studies with the SVT are worth noting. Royer [6] observed a mean error rate of 0.25 (average of all query types), but error rates in the present study are lower by as much as half for all three source material modes (Table 1). In earlier work, Royer [5] also observed that *original* and *distractor* queries were answered correctly at higher rates than *paraphrase* and *meaning change* queries. A plausible explanation for this pattern is that a secondary stage of thought may be required after recognizing that *paraphrase* and *meaning change* queries are only somewhat like quotes of the source materials.

Given that our measures (errors and time to respond correctly) are not Royer's (proportion correct), this trend is nevertheless only weakly evident in our error rates for diagram queries and is not observed in our prose and table query data. Moreover, no evidence of our secondary stage argument—a lag needed for additional thought—is seen in our response time data. Although additional work is needed, key factors in these disparities may be sample size, statistical power, and underlying performance differences in the populations studied by Royer et al. (primary school students) and the largely college-educated population sampled here, with many holding graduate degrees.

4.3 Effect of Contextual Display Format for Tables and Diagram

There was no main effect of the contextual display formats (*with context*, *minus context*, *context free*, and *written*, described above in Subsect. 3.2) on the error rate $F(3,93) = 1.261$, $p = 0.293$, $\eta^2_G = 0.024$. There was a marginally significant interaction between source (prose, table, diagram) and context for error rate $F(8,248) = 1.817$, $p = 0.093$, $\eta^2_G = 0.043$.

There was a main effect of the contextual display format on the response time for correct responses $F(3,93) = 6.384$, $p = 0.001$, $\eta^2_G = 0.056$. Performance with the *written* contextual display format was significantly faster than *with context*, *minus context*, and *context free*, $t(31) > 2.452$, $p < 0.020$. Also, *with context* was marginally faster than *context free*, $t(31) = 1.712$, $p = 0.097$.

There was also a significant interaction between source and context for response time $F(8,208) = 4.765$, $p = 0.001$, $\eta^2_G = 0.082$. In paired comparisons, queries about prose-based information were answered correctly significantly faster than table queries in all contextual display formats, $t(26) > 4.395$, $p < 0.001$[1]. Prose queries were also answered significantly faster than diagram queries in the *context free* and *minus context* formats, $t(26) > 3.335$, $p < 0.003$. No significant differences were found among paired comparisons of response times for diagram queries in each contextual format. Mean response times for table queries were slower than all others in the study. Among these, queries in the *with context* format were answered significantly faster than queries in the *written* format, $t(26) = 2.620$, $p = 0.014$, and marginally faster than queries in the *minus context* and *context free* formats, $t(26) = 2.001$, $p = 0.055$ and $t(26) = 1.738$, $p = 0.094$, respectively (Table 3).

Table 3. Error rates/response times (sec.) by source material modes and contextual formatting.

Prose	0.137 / 8.71			
	Written	With context	Minus context	Context free
Tables	0.266 / 13.38	0.172 / 11.86	0.203 / 13.87	0.141 / 14.63
Diagram	0.141 / 10.20	0.109 / 11.07	0.172 / 11.17	0.078 / 11.35

[1] As was noted earlier, our response time data only corresponds to correct responses. Consequently, five participants who were unable to answer *any* of the queries in one or more of the paired comparisons in this set of t-tests correctly were removed from this part of the analysis.

5 Discussion and Conclusion

Underlying the work in this paper is an applied need for better ways to assess individuals' comprehension of information presented in formats that are different from, but often ancillary to, prose. Most techniques for eliciting a measure of this understanding tend to be time-consuming to compose and also rely heavily on the proficiency of subject matter experts and skilled test writers. To a certain extent, and in spite of its focus on text, the SVT is a proven and successful response to this problem. As a rubric for assessing comprehension, its paradigm of queries that fall into "old" versus "new" information categories is straightforward to implement, and only requires a test writer to know the underlying information domain well enough to derive a plausible set of alternative sentences that do not readily betray their status to a cursory reader. The attractive simplicity of altering source material to query an individual's understanding of it also makes the idea of extending the SVT to other kinds of information seem viable. Doing this, however, presumes that certain functional equivalencies can be made across information formats, e.g., that something like an informational "unit" corresponding to a "sentence" can be defined for, or identified in, information that, on its surface, is not sentence-based.

Our goal in the study presented here was to think through and test some of the ramifications of extending the SVT beyond prose. Our decision to work with tabular and diagrammatic information as it might appear in a SITREP arose from an interest in informational factors that affect decision-making, but we could have as easily chosen comparable, adjunct materials from newspapers, textbooks, or technical reporting. The chief concerns we faced were: determining (a) if (and what) sentence-like units of information could be identified in each of these formats and (b) whether information gleaned from these sources would be sufficiently recalled by a given query without some degree of its original visual context. Addressing the "sentence equivalence" problem was more than a matter of simply depicting individual table cells or single diagrammatic entities. Instead, it was necessary to inventory coordinated relationships that could be depicted and verbalized as assertions. The basic relational pattern identified most frequently in each format was then used as the basis for selecting visual quotes. For tables, this meant showing a table entry with its corresponding row and column headers, and for the diagram, it meant showing node entities linked by an edge together with the diagram's legend. (Other patterns we identified, e.g., multiple informational items in a table cell and grouped nodes, were taken to be variants of sentence equivalence.)

The "visual context" problem, in contrast, centered on the idea of asking readers to evaluate queries displayed as "visual quotes." To be clear, how readers construe context in information formats other than prose is open to question. Along with the knowledge and inferential skills target readers are presumed to have, "context" can arguably be thought of as associative and structural information writers use to coordinate what they want to convey so it can be effectively grasped. Many sentences carry associative references to their prose context with them, and this is generally enough to invoke or recall a sufficient sense of the source's informational cohesion to discern the nature of an SVT query. Most readers, for instance, will likely recognize "the SVT is a proven and successful response to this fiction" as a *meaning change* of part of a sentence from the beginning of this section because of its tacit reference to the first paragraph's topic, viz., how to better assess comprehension of information in formats other than prose. Structural information in prose is implicit in the ordering of sentences and in larger divisions of text, but its contextual importance for comprehension is arguably not as key as referential cohesion is. In tabular and diagrammatic information formats, however, the situation is somewhat inverted. Structure—how and where content is shown—is a conspicuous and potentially meaningful presentation factor, and references to a table or diagram's informational topic are not necessarily carried by individual sentence-like assertions without the inclusion of additional coordinating details. This thinking, then, and intuitions about locational imagery that is often present in focused recalls of depicted information (cf., [12]) led to a straightforward set of contextual formatting conditions, per Fig. 1 above, that were used to assess the extent to which the source information's layout is or is not needed to most effectively pose visual SVT queries.

Our findings clearly show that the SVT can, in fact, be functionally extended beyond prose and, moreover, that depicting queries based on "visual quotes" is a viable way to evaluate a reader's understanding of both tabular and diagrammatic information. Visual queries took up to six seconds longer to assess than prose, but error rates overall were lower and somewhat more uniform than expected. To explore these patterns, post-study, we scored each information mode in the SITREP (excluding the map) for readability. Using [14] for the prose portion and [10] for the tables and the diagram, with the latter recast as an adjacency matrix, all three categories were found to be approximately at, but no higher than, a first-year undergraduate level of difficulty and thus well below the general educational level of our readers. This comparative lack of complexity across all three sources may have contributed to the observed pattern of error rates, both broadly and across query types. It cannot, however, account for the clear differences in response times observed in the study. Two factors that may have hindered the table and diagram query assessments are information content and cognitive effort. In our inventory of assertions, we respectively identified 20, 47, and 31 propositions in the prose, table, and diagram portions of the SITREP. The correspondence between these numbers and the pattern of response times in Fig. 2 suggests that readers may have simply needed more time to consider a query when a larger degree of underlying information was involved. In addition to any effort arising from these information loads, the respectively different skills readers need to attend to and encode different media [4] may have also had a role in the pattern of response times. Plausible evidence of this can be glimpsed in the source/context interaction in Sect. 4.3 wherein showing table queries *with context* notably improved response times relative to the other contextual formats. This was one of the outcomes we anticipated, based in part on cognitive performance principles relevant to our experimental design, e.g., Gestalt laws of grouping [15] and encoding specificity [12], but an analogous result was not found for diagram queries. Still, this may only reinforce the fact that there are substantial procedural differences between the practiced skill of reading prose and less frequently exercised skills involved in reading tables and diagrams that continue to warrant further study. Use of a talk-aloud protocol per [16] in future work may help to provide a clearer account of these differences.

Last, this work illuminates an important challenge for comprehension studies with different information formats in an integrated document. Our experimental design required repeated checks to ensure that *meaning changes* and *distractors* did not make assertions that could be unwittingly conflated with the reader's encoding of the SITREP and foil other queries. The prose query that had to be removed from our data (see Sect. 4 preamble) underscores the extent of this risk, and references to use of the SITREP's map in post-study questionnaires show that merging adjunct informational materials into a larger narrative is a common reading and encoding strategy.

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Increasing Flexibility of Employees in Production Processes Using the Differential Learning Approach – Adaptation and Validation of Motor Learning Theories

Kirsten Weisner[1(✉)], Marco Knittel[1,2], Thomas Jaitner[2], and Jochen Deuse[1]

[1] Institute of Production Systems, TU Dortmund University, Leonhard-Euler-Straße 5, 44227 Dortmund, Germany
{kirsten.weisner,marco.knittel, jochen.deuse}@ips.tu-dortmund.de

[2] Department of Sport and Sport Science, TU Dortmund University, Otto-Hahn-Straße 3–5, 44227 Dortmund, Germany

Abstract. International expanding markets and continuous development of new customer oriented products lead to an increasing product and process variety and complexity as well as shortened product lifecycles. According to these challenges, manufacturing companies have to enhance their process flexibility to remain sustainable competitive. Due to that, employees have to deal with high flexible work processes including continuous change of constellations and objectives. These in turn require a high employee's flexibility, adaptability and occupational competence as well as new training concepts to enable them. In the academic literature and industrial practice, exists a variety of concepts for employee's qualification and training. However, these concepts do only partially focus the employee's occupational competence. Therefore, an innovative learning concept based on motor learning theories was developed and empirically validated. The description of the examination design as well as the result presentation and discussion are subject of the present contribution.

Keywords: Competence development · Assembly processes · REFA Differential Learning · Task variation · Individuality · Motor learning

1 Introduction

Volatile markets, new global competitors and an increased market saturation are only some examples of the current challenges faced by manufacturing companies. To remain competitive, a fast and flexible response to ever-changing market and customer demands is necessary [1, 2]. In this context, one strategy pursued by many companies is the so-called customer orientation, which leads to an increasing variety of variants. The differentiation from competitors can exploit existing market potential and finally increase the companies' sales. In addition, the increasing variety of variants is accompanied by decreasing batch sizes, more frequent set-up processes, decreasing cost degression and

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lower learning effects among employees [3, 4]. Assembly processes are the last production step in the supply chain. Due to the close proximity to the customer and the connected variety of variants, they are particularly affected by frequent product changes as well as decreasing quantities per type and batch sizes [5].

The required level of responsiveness to dynamic market developments can only be met by employee's time, content and spatial flexibility. Creativity, flexibility, problem-solving ability as well as experience and know-how of the employees are often the only way to gain assembly systems that are resistant to different disorders. In summary, employee's abilities are of central importance to fulfill the individual customer requirements reliably. The sole knowledge of existing causal relationships is indeed the essential basis for efficient work, but not sufficient due to the high dynamics of change. This means, that the mere transfer of theoretical knowledge does not meet the current requirements. Instead, employees need to be empowered to develop their own situational behavior strategies and successfully implement them to solve continuously changing problems [6–8]. Against this background, the development of competences gets increasingly important. Competences are defined as dispositions of independent and self-organized actions. In addition to a high level of expertise, occupational and problem-solving competence are a feature of sustainable and very successful companies [9, 10].

In industrial practice and scientific literature do exist numerous approaches and methods for training and qualification of employees in industrial manufacturing and assembly (e.g. TWI). However, these are primarily used to learn new skills and less to specifically support occupational competences of employees. As well, the often discussed possibility of competence development by so-called simulation games and learning factories focuses only to a limited extent on the flexible employment of employees. Instead, rather the optimization of work systems with the involvement of the knowledge and skills of operative employees is paramount. However, there is no targeted, systematic and work-related approach for developing occupational competence.

For this reason a new approach for developing occupational competences was developed at the TU Dortmund University and is subject of this paper. This approach should enable employees to deal with the increased variety of variants in an efficient und sufficient way. The approach has been empirically investigated and compared to a well-known training approach (REFA-Work instruction).

1.1 REFA-Work Instruction (4-Step-Method)

The REFA-Work Instruction consists of four consecutive steps and was transferred to REFA basic training in 1951. It has been since then the best-known methodical variant of work instruction in Germany [11]. It is a directive educational, trainee-oriented method, which works according to the principle of "demonstrating and imitating" and is therefore called a form of imitation learning [12, 13]. The method is used in particular for teaching extensive assembly or production tasks. Focus is on manual, relatively short-cycle and simple-structured processes that are repeated according to a standard in a defined sequence and that allow a certain degree of motion automation [11]. Prerequisites for the successful application of REFA-Work Instruction are the segmentation assembly processes as well as the linking between the activity to be learned with language. The latter serves to promote the mental re-enactment and understanding of the tasks to be learned [13].

The REFA-Work Instruction is a simple applicable and efficient standard method for instructing assembly workers. The method's focus is not only on the right implementation of assembly processes or in motor skills of work processes, but rather on the goals and reasons or justifications for assembly processes [13, 14]. Rigid teacher's specifications allow a quick transfer of knowledge, an immediate sense of achievement as well as an immediate success control. In addition, limited action regulation also requires trouble-free learning processes, whereby the production goals are sometimes met very quickly [15, 16]. However, precisely the rigid approach impairs self-reliant or self-directed learning. Thus, the teacher teaches the learner in an ideal way of working, possible alternatives are not explained and instructed. In addition, the REFA-Work Instruction requires a great deal of effort on the part of the teachers. Contents of the individual levels must be redefined and reconciled for each new activity to be taught; transferring to other contents is rarely possible [15].

The four steps of REFA-Work Instruction are preparation (1), demonstration (2), execution (3) and completion (4). Preparation includes the professionally methodical preparation, the determination of the learners' previous knowledge, and the mention of the learning objectives as well as the awakening of interest by the teacher. The actual learning of the assembly tasks takes place in the stages two to four.

During the empirical study, the assembly processes, which had to be learned, were first demonstrated by the experimenter while participants were informed about the entire sequence of movements and the defined key points. In this way, an overall process understanding was established. During the third step, the participants assembled independently and explained their approach in parallel. The accomplished connection between action and speech was an essential prerequisite for the consolidation of the learned processes. The experimenter assisted the participants in this phase by helping, advising and correcting. In the fourth step, participants practiced the assembly independently; experimenter had only (interval) checks to do. Concerning this, participants were enabled to self-control.

In summary, focus was on teaching a previously defined standard of work execution including defined sequence of process steps and two-handed work. Implementation requires a close accompaniment of the experimenter by regular inspections and detailed explanations as well as intensive discussions of key points.

1.2 Differential Learning for Assembly Processes (DL)

Analogous to numerous concepts for employee's qualification and training, traditional approaches of motor learning focus on learning a person-independent ideal movement. However, several empirical studies have identified two central characteristics of human movement: non-repeatability and individuality. The traditional methods, which include learning movements by many repetitions and under consideration of an ideal movement, are fundamentally queried.

In this context, Schöllhorn developed the Differential Learning (DL) approach, which is based on the system dynamic approach of the movement sciences. On the one hand, the basis of this approach is the self-organization of dissipative systems. On the other hand, the approach assumes that the increase of fluctuations within the execution of movement during the learning process, has a performance-enhancing effect. Considering the work of [17] (e.g. HKB experiment) stochastic differences in the execution of movement in terms of content and time are mandatory requirements for effective motor learning according to the system dynamic approach. Therefore, an essential characteristic of DL is the constructivist understanding of variability. For example, the orientation towards a defined standard or ideal movement is deliberately queried. The variability and flexibility are purposefully used as a requirement for learning itself. The aim of DL is to improve the self-organization of learners and thus to be able to react to changing ambient conditions in the best possible way. Summarizing, the focus of the approach is "learning of adaptation" and not learning of a repeatable ideal movement [18]. Positive effects of DL could be demonstrated in various sports disciplines (e.g. performance enhancement, stabilization of output, improved adaptability as well as optimization and temporal stabilization of skills and abilities) [19, 20]. Please refer to [18, 19] for a detailed description of the system dynamic approach and the DL.

By constantly confronting people with changing tasks, their dynamic abilities can be strengthened. Thus, people get qualified to react quickly and adequately to new tasks and changed ambient conditions. Within the framework of motion sciences, [18] defines the following ranges of variation: joint angle, joint angular velocity, joint angular acceleration, boundary conditions of the movement and attention to individual movement aspects.

Under consideration of that, different parameters for variation in industrial assembly processes were identified: type of movement (initial and final conditions, scope), used materials and equipment as well as the environment's design. In order to achieve a change in the movement execution, the participants were trained at different workplaces, which were characterized by a different material supply. Thus, material was provided in different containers, which were located at different workplace's areas or the material was either mixed, isolated or pre-picked and sorted. In addition, the height of the workstations and the level for the material supply was varied and changing devices, workpiece carriers and tools were used. Changes in the environment design were simulated by wearing ear protection and sunglasses. Furthermore, to vary the joint angular velocity and acceleration, the participants were sometimes limited in their freedom of movement. For this purpose, overalls, balance-pads, weights on forearms and gloves were used. In addition, the assembly was done both, standing and sitting on different chairs. It has to be pointed out that the participants were only instructed to assemble the product without errors. No assembly sequence was set, which means that no ideal assembly process was defined. In addition, the mentioned variations were varied over time. The participants performed the assembly cycles with the respective variations only once. An overview of all variation used in the empirical study is shown in Fig. 1.

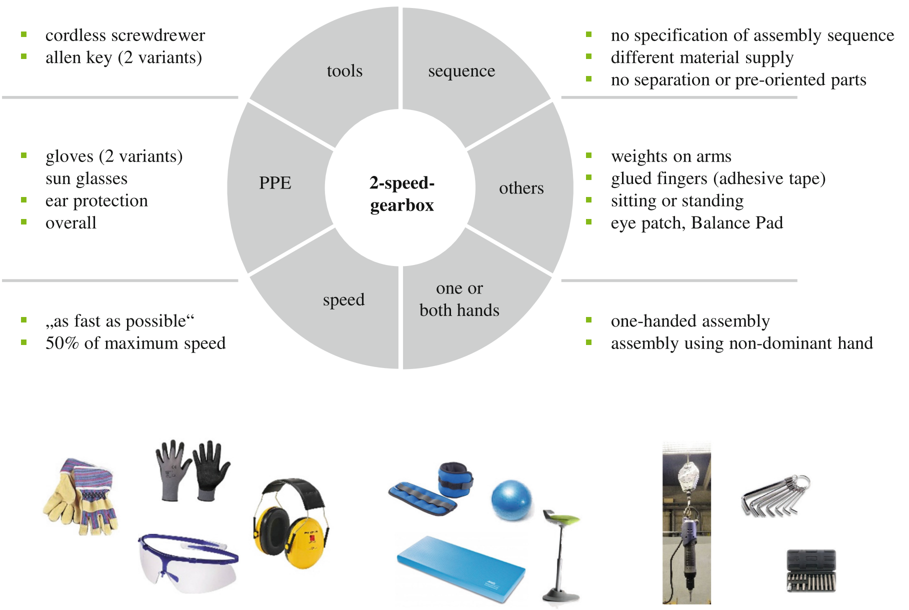

Fig. 1. DL in industrial assembly processes: variations

2 Methods

The empirical study's aim was the validation of the developed differential learning concept for industrial assembly processes. One main aspect was the change of employee's performance over time depending on used training concept. For this purpose, it was necessary to define a study design with at least two measuring points (pretest and posttest). In addition, the temporal and long-term stability of the change in employee's performance was examined as a function of the learning concept as well. This was done by adding a retention test into the study's design. Furthermore, the main objective of adapting the DL for assembly processes, was the development of individual's occupational competence, which in turn enables employees to act in complex and uncertain situations in a self-organized and responsible manner. For that reason, the adaptability of performance to other contexts was examined in two transfer tests. Finally, the performance's constancy over time respectively during different test was of particular interest. Due to that, dispersion measurements (e.g. standard deviation) were evaluated in addition to pure location parameters. The developed design of the empirical study is shown in Table 1. Both experimental groups (REFA, DL) assembled the same number of products during the intervention phase (28).

Table 1. Study design

Introduction	Intervention							Retention
Week 1		Week 2		Week 3		Week 4		Week 5 + 6
1	2	3	4	5	6	7	8	9
• Motivation • Organisation • Practice	• Pretest	• Randomized division into two groups (REFA, DL) • Practicing assembly in five meetings					• Posttest • Transfer test 1	• Posttest • Transfer test 2
60 min	60 min	60 min/meeting; total: 360 min					90 min	90 min

2.1 Workplaces, Products and Data

The empirical study took place from September to December 2017 in the Industrial Engineering Training Centre of the Institute of Production Systems (IPS) in Dortmund. When designing the assembly work places (see Fig. 2), the DIN EN ISO 6385:2016 was taken into account. In addition, the designed work places were subjected to a risk assessment.

Fig. 2. Designed manual workplaces including different material supply

During pretest, posttest and retention test, the participants had to assemble a 2-speed-gearbox in six assembly cycles. During transfer test 1 they had to assemble a pump (six assembly cycles) and for transfer test 2 a desk lamp was chosen (four assembly cycles). Different product are shown in Fig. 3.

During the different tests, cycle times as wells as assembly errors were recorded. Since the subjects received no feedback during the tests, the following types of errors were detected and rated (points): no error (0), repetitive error (0.5), error (1). In addition, after each test subject's mental stress was detected (RSME, NASA-TLX, HRV).

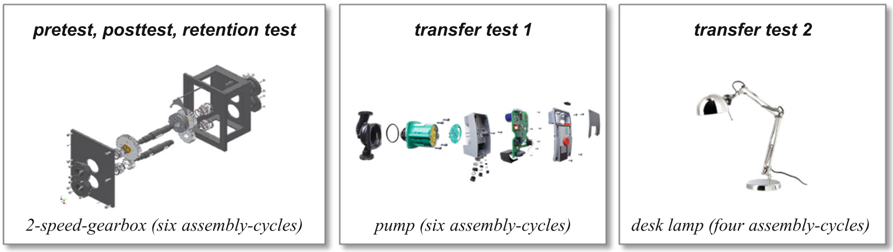

Fig. 3. Assembled products in different tests

2.2 Sample

The study involved n = 22 subjects. In addition to the demographic data, the subjects were interviewed about their previous experience in the field of assembly. Their experience was achieved by using a six-step Likert scale (1 = no experience, 6 = extensive experience). The composition of the sample(s) is shown in Table 2.

Table 2. Sample's composition

Group	n	f	m	Age (median) [years]	Range (min-max) [years]	Experience (median)
REFA	11	4	7	27	40 (21–61)	3
DL	11	4	7	25	42 (22–64)	2
Total	22	8	14	27	43 (21–64)	2,5

3 Results

Concerning sample size and distribution of collected data, parametric methods were used for interference statistical analysis. Comparison of mean values regarding cycles times, mental stress and error-points was done using a t-test. In addition, an ANOVA with repeated measurement was carried out as well to compare the collected data of pretest, posttest and retention test. An elimination of outliers was not carried out. An error probability of 5% was assumed. Figure 4 shows selected results of the different tests.

Table 3. Cycle time during pretest, posttest and retention test

Group	Pretest (T_0)	Posttest (T_1)		Retention test (T_3)	
	X [s]	X [s]	$T_0 - T_1$	X [s]	$T_0 - T_2$ ($T_1 - T_2$)
REFA	382,33	279,22	–27%	302,04	–21% (+6)
DL	358,23	270,96	–24%	279,42	–22% (+2)

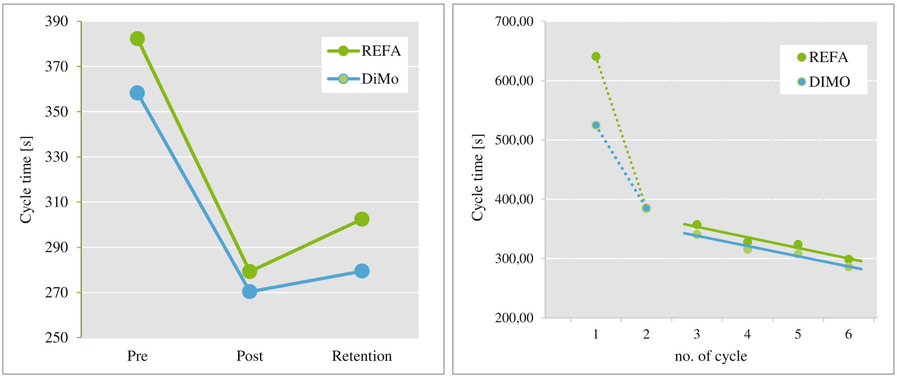

Fig. 4. Results of pretest, posttest and retention test (left); results of transfer test 1 (right)

3.1 Pretest, Posttest, Retention Test

The expectations for pretest, posttest and retentions test were met. The control group (REFA) had a significant decrease concerning cycle times between pretest (T_0) and posttest (T_1) of 26%. The comparison of T_0 with the retention test (T_2) shows a significant increase of performance as well (cycle time reduction: 21%) This corresponds to a performance loss over the retention phase of five percentage points. The intervention group (DL) hat a significant decrease concerning cycle times between pretest (T_0) and posttest (T_1) of 24%. The comparison of T_0 with the retention test (T_2) shows a significant increase of performance as well (cycle time reduction: 22%). This corresponds to a performance loss over the retention phase of only two percentage points. There is no significant difference in performance between both experimental groups (see Table 3).

The standard deviation (SD) of cycle times as well as the results of the recorded mental stress (RSME) are nearly the same. While there is a significant difference between pretest, posttest and retention test or each group itself, there is no statistical significance between both experimental groups.

3.2 Transfer Test

When evaluating the first transfer test, there was no clear trend in mean cycle times. However, if the first assembly cycle is considered in detail, it can be stated that the cycle times between both groups differ significantly. In addition, the assembly performance (cycle time) of the intervention group (DL) is much more constant. Thus, the standard deviation (SD) of the control group is on average much higher than the SD of the intervention group. The same applies to the collected average mental stress (RSME) (Table 4).

Table 4. Results of transfer test 1

Group	X [s]	SD [s]	RSME	X [s] (1^{st} cycle)
REFA	388,81	120,48	98,82	640,72
DL	360,01	88,78	77,36	524,81

4 Conclusion

To handle the increasing variety of variants in a successful way, human work is of outstanding importance. Indeed, theoretical knowledge and expertise of employees is not enough for the design of efficient assembly processes. Instead, it is necessary to develop individual competences to handle the increasing processes complexity. The term competence includes the ability of acting in a self-organized and creative manner and dealing with vague or missing goals as well as indeterminacy. In this context, occupational competence, which in turn enables employees to act in complex and uncertain situations in a self-organized and responsible manner, is of particular interest. Today, there is no targeted, systematic and work-related approach for developing occupational competence. To close this gab, an innovative approach for developing occupational competence has been developed at the TU Dortmund University and was subject of this paper. The approach is, based on the DL from the research field of the movement sciences.

The developed approach has been successfully validated in an empirical study. Analogous to the REFA-Work Instruction, the DL for assembly processes leads to significant performance increases concerning cycle times. During the retention phase, the new approach even resulted in less deterioration concerning the temporal and long-term stability of the change in employee's performance. During the transfer tests, it was observed that the DL assembly processes leads to significantly lower cycle times within the first assembly cycle. In addition, the SD and the mental stress (RSME) were lower over all assembly cycles in the transfer tests.

In the future, it will be necessary to carry out more detailed investigations regarding gained learning achievements as well as existing correlations between learning performance, fault patterns and mental stress. Due to the positive findings, the DL for assembly processes has to be detailed. It has to be analyzed to what extent the degree of variation can be quantified, so that an optimal degree of variation can be defined for a given assembly task.

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Evaluating Training Efficacy and Return on Investment for Augmented Reality: A Theoretical Framework

Amanda Bond[1(✉)], Kelly Neville[1], Joseph Mercado[2], Lauren Massey[1], Adam Wearne[1], and Sherry Ogreten[1]

[1] Soar Technology, Inc., Orlando, FL, USA
{amanda.bond, kelly.neville, lauren.massey, adam.wearne, sherry.ogreten}@soartech.com
[2] Naval Air Warfare Center Training Systems Division, Orlando, FL, USA
joseph.mercado@navy.mil

Abstract. Augmented Reality (AR) has been in existence since the 1960s, however there is a lack of empirical research of areas in which using AR technology have the most benefit – and which areas do not see positive impacts. Being able to identify tradeoffs involved in acquiring and deploying an AR-based training system with respect to utility, efficacy, and return on investment (ROI) are valuable to any training program and acquisitions manager. In order to address this innovation gap, we present the Media Efficacy Return on Investment Tool (MERIT). MERIT is a theoretical framework methodology for quantitatively evaluating AR and other training solutions for a given training environment based on four factors: Task Factors, Training Media Factors, Return on Investment (ROI) Factors, and Training Efficacy Factors. The MERIT framework, based upon the "House of Quality" matrix, helps compare, visualize, and assess user and technical requirements as well as research gaps.

Keywords: Augmented Reality · Training · Training efficacy Return on investment · Human systems

1 Introduction

Augmented Reality (AR) as a concept has been in existence since the 1960s, however it wasn't until the 1990s that AR research began in earnest for human performance enhancement. The late 1990s and early 2000s saw AR implemented in operational domains for military and defense applications as well as in commercial aviation. AR has been used in fighter pilot cockpits for some time, projecting information such as glide path, runway aim points, the locations of other aircraft, or the next navigation point in a heads-up display [1]. By the late 2000s and through the 2010s AR has continued to see technological leaps in accessibility and affordability with systems such as Google Glass and the Microsoft HoloLens becoming available to the general public.

AR has become more prevalent in recent years as the research use cases have bled into real-world applications, particularly with the advancement of wearable technology such as Microsoft's HoloLens. AR has the ability to put synthetic people, places, and

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things into a user's augmented view so that they can interact with synthetic entities within the real world. As evidence of this, AR is currently being used in a wide gamut of tasks. AR is used to guide surgeons remotely when they are operating on patients, for navigation assistance and wayfinding for driving [2], and to show customers what a high-end vehicle would look like if a specific color or trim is ordered [3]. Mobile-based AR is also on the rise as smart phones become ubiquitous in today's society, with apps like astronomy app Star Chart and the briefly wildly-popular game Pokémon Go.

Despite these advances, however, AR as a whole is still largely underutilized in areas in which the enhancement of human performance can have the most benefit: operations and training. This is because in many ways, AR is a technological *solution* without a clear set of general guidelines for what *problems* AR solves and to what efficacy. AR is instead perceived as a "nice to have" or as an extraneous flashy marketing gimmick [4]. AR, however, is a potentially powerful tool for operations and training, and when compared to solutions such as expensive simulators and operational systems, may be a more cost-effective training modality. The military is increasingly using AR systems for training force-on-force tactics, dismounted maneuvers, forward observation, maintenance, and many other skills, however limitations of current augmented systems impede more widespread use for training. For instance, AR applications exist (e.g., the AITT program [5]) that show virtual objects overlaid in the outdoors, but these distant views require involved up-front measurement and positioning. However, AR is shown in *specific use cases* to speed up the training process, saving time and money, and allows trainees to be transported to scenarios and situations that are difficult to simulate in live exercises (e.g., [6]). Despite these one-off findings, AR for training hasn't yet been widely used or studied with respect to training efficacy, particularly when considering other potential training media.

2 The MERIT House of Quality

Quality Function Deployment (QFD) [7] is a methodology used to assess user requirements (what the user wants) against technical requirements (how these requirements might be met from a technical standpoint). The "House of Quality" (HoQ) matrix is specific tool within QFD that helps visualize and assess these different requirements, specifically to identify tradeoffs and areas where work needs to be done to meet the requirements (see Fig. 1). Similarly, MERIT creates a theoretical framework for the comparison of different training media types based on efficacy, utility, and return on investment (ROI), focusing on AR media as it compares to other training media. Specifically, the four comparative factors are: (1) task training factors, (2) media factors, (3) efficacy factors, and (4) ROI factors. These four factors are related algorithmically to each other and within the factor dimensions in order to evaluate the efficacy and relative ROI for various training media for a given task. Training acquisition managers are then able to input task training factors, adjust media factors, and input ROI factors to obtain an overall score for various media solutions.

The left column lists the user requirements (along with ranked importance), and the top row lists the technical requirements. The matrix in the middle identifies how pairs relate: the symbols indicate weak to strong relationships. The triangle matrix at the top indicates pairwise dependencies between technical requirements. Across the bottom is a ranked assessment of difficultly of achieving each technical requirement, as well as a quantitative (computed) assessment of relative importance of addressing a technical requirement. The rightmost matrix and graph captures how well current products meet the listed user requirements.

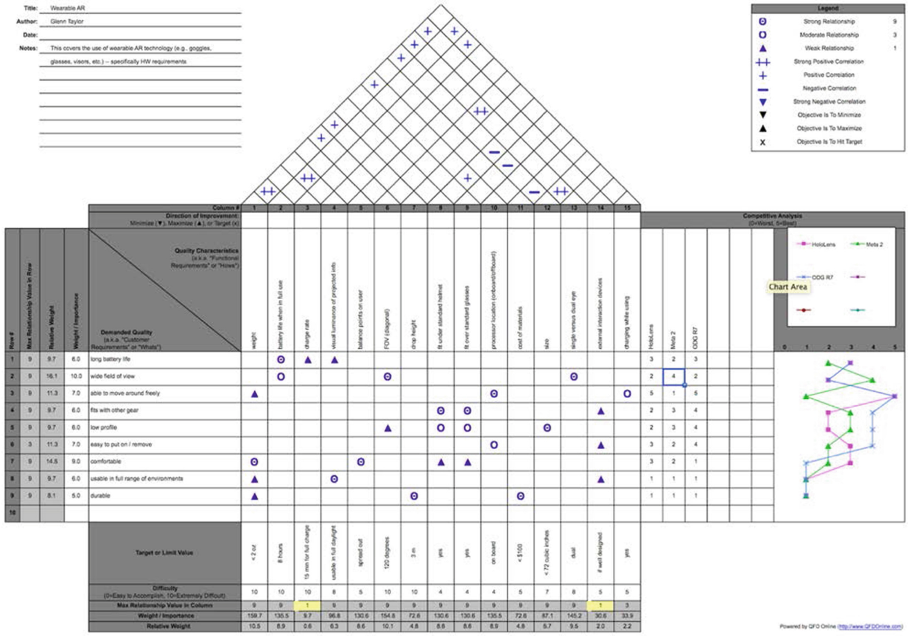

Fig. 1. An example quality function deployment of the house of quality matrix, specifically for augmented reality in army mission command.

2.1 The MERIT Framework: Research Methodology and Foundations

In order to map training technologies to the MERIT HoQ, we reviewed training technology literature to identify major categories of technology, training objective (i.e., task characteristic targeted by training), and instructional strategy. As discussed below, a majority of training technology research articles unfortunately did not report effect sizes or clear statistical outcomes. Further, many focus on the qualitative benefits found by using a given training technology, rather than present a comparison of two or more technologies.

The articles reviewed included both publicly available articles and articles that required access to a library service. Both qualitative and quantitative studies were included. Similarly, both experimental and naturalistic studies were included. We only required that the article describe a literature review or meta-analysis or present one or more studies. Most of the studies evaluated the use of technology to teach classroom subjects, and in these, the students ranged from elementary school to medical school students. A small number focused on the training of professional skills such as system maintenance.

Six review articles were included in our analysis; two of which were judged to be high quality and so played heavily in the identification of HoQ categories. In addition, 24 original research articles were reviewed and used to define the categories and fill in matrix cells. We assert that these research articles, together with the review articles, provided a solid understanding of which instructional strategies and training objectives construct a reasonable framework for comparing augmented reality, virtual reality, or a basic computer-based training approach. It is intended that the MERIT framework can continue to be expanded, thereby enriching the technology-usage knowledge contained within it.

The definitions of HoQ categories were initially based on the findings of a meta-analysis [8] and literature review [9] of research investigating the use of augmented, virtual, and mixed reality in training and education. These works emphasize the importance of using instructional strategies that take advantage of a given technology type's affordances. They additionally emphasize the importance of mapping training objectives to a technology based on that technology's affordances. Both recommendations are reinforced by the MERIT HoQ, which will help training technology and acquisition professionals follow these recommendations and thereby optimize training technology employment.

The aforementioned work [8, 9] contributes significantly to the groundwork for identifying MERIT HoQ categories. Specifically, as an initial step in MERIT HoQ category development, we adopted the two articles' mappings of technology type to training objectives and instructional qualities, given the affordances of each technology type.

Example training affordances identified for AR technology [8, 9] include the following:

- *Real world annotation*: Digital content can be inserted into real-world scenes and events to enrich them with educational material and provide scaffolding.
- *Contextual visualization*: Digital content can be inserted into real-world scenes to transport learning into a real-world, operational setting, which helps overcome transfer-or-training challenges.
- *Vision-haptic visualization*: Digital content can be both viewed and manipulated.
- *Portability*: The ability to take the educational experience out of a classroom and present it in a park, museum, or other nontraditional setting.
- *Social interactivity*: Because AR systems project digital information and images into a real-world environment, they allow more than one person to view digital content in parallel.

For MERIT, these and other affordances were translated into instructional strategies we included in the HoQ (see Table 1). For example, the affordance *real world annotation* maps to the HoQ instructional strategies *scaffolded* and *situated learning*. A user of MERIT will be able to look up the intersection between each of those strategies and different training technologies to find indicators of the amount of research investigating each combination and whether or not that research revealed a benefit of the instruction strategy-technology combination for learning outcomes.

Table 1. Training affordances of AR and associated MERIT instructional strategies

Example AR affordances	Instructional strategies in MERIT that reflect each affordance
Real world annotation	Scaffolded Learning Situated Learning
Contextual visualization	Situated Learning
Vision-Haptic visualization	Physical Interaction Active Learning
Portability	Situated Learning Active Learning
Social interactivity	Social Learning Theory (Observation) Collaborative Learning Game Based Active Learning

As can be seen in Table 1, each of the AR affordances identified facilitates situated or active learning [8, 9], both of which have been identified in the learning science literature as having extremely powerful positive effects on learning and long-term retention (e.g., [10–13]). Accordingly, users of the MERIT HoQ will find AR to be a recommended technology when learning can take place within the actual performance environment or when AR will be used to support manipulation and active visualization of aspects of or elements within the operational environment.

By contrast, we also captured guidance on *when a particular technology should not be used*. The MERIT HoQ will reflect these negative relationships as well as the positive. For instance,

- It can be difficult for an instructor to oversee and guide learning or provide feedback when a learner is interacting with a virtual or operational environment through a head-mounted display. If real-time instructor involvement or process feedback are desired, technologies such as head-mounted displays that limit instructor access to learner activity tend to be problematic.
- AR can introduce artificialities to a high-fidelity training environment. Those artificialities have the potential to produce negative training (e.g., [14]).

We also captured from literature reviews the types of knowledge and skills that seem well-suited to the affordances of a particular training technology. Types of knowledge and skill found to be particularly suited to the affordances of AR include the following:

- Knowledge about and understanding of causal relationships, especially within complex system models
- Knowledge about spatial relationships
- Visuo-spatial skills
- Psychomotor/perceptual-motor skills

2.2 The MERIT Framework: Structure and Organization

The MERIT categories was evolved and refined as we conducted the research literature review. Research papers we reviewed enriched our understanding of technology type affordances and the basis for training objectives and instructional strategy categories. Training efficacies reported in research articles were dependent on situational factors including the training objectives (e.g., subject matter to be learned) and instructional strategies used. We focused on capturing those factors so that training efficacy could be understood not in terms of the technology per se (e.g., AR vs. VR), but rather in terms of the technology in context. By *technology in context*, we mean characterizing the technology in the instance described in the paper, capturing the leveraged technology affordances plus training objectives, instructional strategies, and any other factors weighing into the assessment outcome. The lists of training objective, task, and instructional strategy categories identified based on this baseline HoQ development work can be seen in Table 2.

Table 2. MERIT HoQ task and instructional strategy categories

Instructional strategy	Type of knowledge to be acquired	Type of skill to be acquired	Performance requirement
Active, inquiry based	Spatial Relationships	Gross motor movements and positions (via demo and feedback)	Recall taught concept
Active, exploratory	Complex conceptual, abstract knowledge	Fine motor movements (via mimicry, compare and contrast)	Explain and understand concept
Compare-and-Contrast	Declarative knowledge about real-world objects	Recognizing perceptual details (sensory cues)	Demonstrate use of concept
Game-based	Interactions between/among variables; Cause-and-Effect relationships	Spatial reasoning/judgements	Compare and contrast concept
Physical interaction	Obscured, invisible, or inaccessible system dynamics	Task/work actions that are not keyboard/mouse based	Evaluate concept
Problem/Case-Based	Physically or geographically distributed	Teamwork	Develop new or original work from concept
Scaffolded	Team member support needs		
Situated/In actual performance environment			
Social learning theory; Observation			
Social/Collaborative learning			

As can be seen in Fig. 2, categories of technology became HoQ column labels. Categories of instructional strategy became a block of HoQ row labels. Categories of training objective became a second block of row labels, split into knowledge-based and skill-based objectives.

The different categories of row labels represented a deviation from the traditional HoQ, which typically contains a single set of customer or stakeholder needs. We deviated further from the traditional HoQ by adding *patios* to the left vertical axis (see Fig. 2). The patios resemble the traditional HoQ "roof" that runs over the upper horizontal axis and is used to capture conflicts and compatibilities among technical solutions. The patios similarly capture conflicts and compatibilities, but capture those occurring between the instructional strategies and training objectives. In this way, we were able to adapt HoQ structural elements to represent critical variables and interactions within the decision space, versus oversimplifying or forcing the variables and interactions to fit.

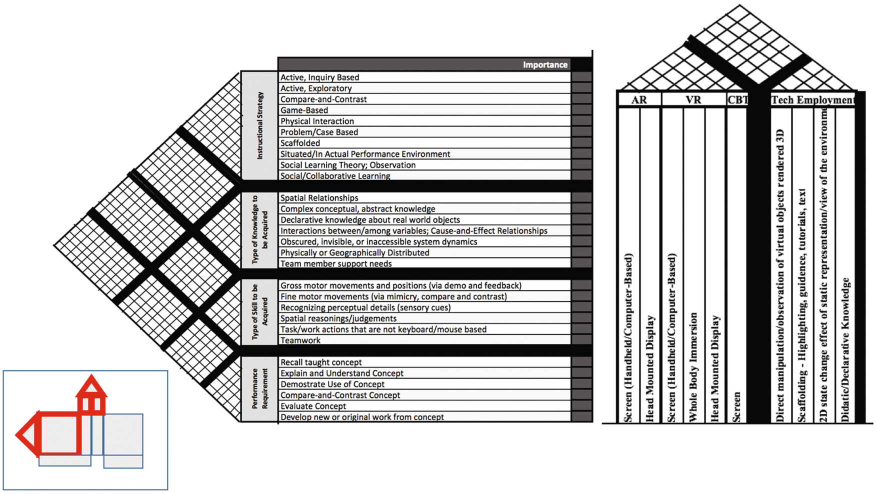

Fig. 2. The MERIT HoQ technology categories (vertical "roof") and task. Training categories (horizontal "patio").

The HoQ structure is a *living artifact* that can be adapted to handle future technologies and research findings. For this research, we evaluated the landscape of AR and VR systems, including the variety of forms they take, the training objectives and instructional strategies they tend to support, the extent to which they benefit training, and the quality of the research articles. HoQ cells were filled using results reported in reviewed research articles considered together with article quality measures. Cell contents indicate the extent to which research results support the use of a given training technology for (1) implementing a given instructional strategy (i.e., its compatibility with the strategy's affordances) or (2) achieving a given training objective. The entire HoQ can be seen in Fig. 3.

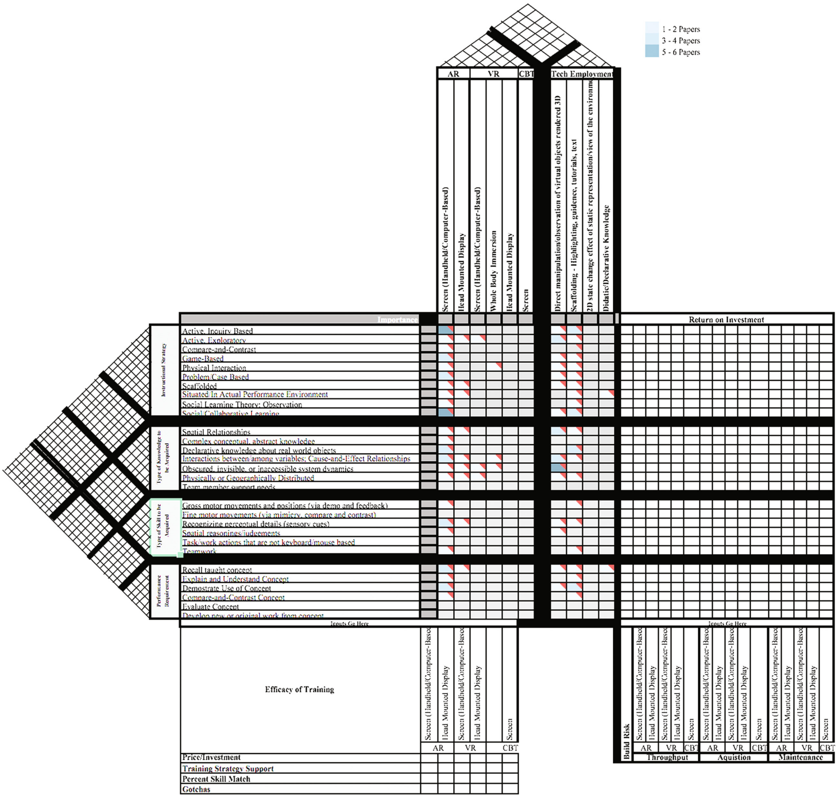

Fig. 3. The complete MERIT House of Quality.

3 Algorithmic Computations

The overarching goal in this step of the MERIT framework development was to calculate the correlational structure of the data. In constructing the correlation matrix, we require some set of data that in some way encapsulates the efficacy of various training media at training some set of tasks. This dataset was derived from an analysis of research articles, as described previously. In the general case, we envision that each observation in the dataset under study will be multi-variate in nature and consist of two "types" of variants. To use the parlance of the standard HoQ framework, these consist of Customer Attributes (CA) and Technical Attributes (TA). As their name suggests, CAs consist of the set of needs or requirements of the customer. In the case of MERIT, the CAs represent both training tasks and how the training media might be used. The TAs refer to the technical solutions that may be employed to best meet the customer's requirements. For MERIT, this refers to the set of possible training media.

Perhaps the best choice suited for the current instantiation of MERIT is ordinal data. While it precludes the use of parametric statistics and factor models, we can incorporate metrics regarding paper quality and consistency of results into a Likert scale.

The process begins by first aggregating available research articles and presenting them to a team of expert reviewers who first rate each article on a number of criteria which reflects the overall quality of the research conducted. Rubric items for this evaluation include topics like number of participants, research methodology, and data analysis practices. After thorough discussion of each article, each paper is assigned a score related to its overall quality. Papers are then separated based on their relevance to each CA/TA. To map the quality of the research score in the previous step to an ordinal score that reflects the efficacy of training a given proficiency, the following prescription is followed.

For a given CA, we gather all papers relevant to that proficiency. Using these sources, we can form a triplet of scores representing the total scores of high-, medium-, and low-quality scores for this CA. This raw score vector, s is then normalized. Finally, we produce a weighted sum of the normalized score vectors with weights given by the fraction of total papers that were used in computing the original raw score. This produces a final value in the interval of [0, 1], which can then be mapped to ordinal values by partitioning this interval.

With this information, we then have data for each CA and TA of the form, as Table 3 illustrates:

Table 3. MERIT HoQ task and instructional strategy categories.

Obs. Num.	CA1	CA2	CA3	CA4	CA5	TA1	TA2
1	3	9	9	7	5	8	7
2	6	6	6	1	3	1	6
3	0	3	2	8	7	0	10
4	10	3	1	2	5	5	7
5	4	5	3	0	9	8	0

Given the data in this form, we then apply non-parametric approaches (Spearman, Kendall, etc.) to assess the correlation structure of the data.

Irrespective of the particular data format used, the end goal in all cases is the calculation of the correlation matrix, $\hat{p}$. It contains all information regarding the efficacy of combinations of training media and training tasks. We will use this information to give the end-user feedback on what training media may be most beneficial for fulfilling their training requirements. As part of the MERIT framework, the user is prompted to select the tasks they would like to use for training and to indicate the corresponding level of importance to the user. We represent these weights as a vector w with a dimension corresponding to the total number of tasks able to be trained. A numeric score representing the efficacy of each training media on the chosen tasks that balance the user's preferences is then given by

$$\text{task score} = w^{\mathrm{T}}\,\hat{p}. \tag{1}$$

By sorting the scores by their value, the MERIT framework can then present the user with the training media that best balances their preferences. This process serves to help answer the question: "Given a set of training tasks, what training media are best suited toward increasing a trainee's proficiency?" Conversely, one could also use this process to answer the reverse scenario with a different weight vector that measures training media preferences. This inverse problem would then help with the question of: "Given a set of possible training media, what tasks can be trained most effectively?" This second question is not examined within the current architecture of MERIT, but could be a point of future work. In addition to specific training tasks, we also consider the set of *usage* cases which typify *how* the training media might be used. Examples of such usages include the following: requiring didactic/declarative knowledge, scaffolding, 2D state change effects, and direct interaction with rendered 3D objects. A separate weight vector, v can then be employed for usage preferences, and in a manner identical to that described above, we can obtain a sorted list of training media according to how well they balance the user's usage preferences. By comparing both the set of usage scores and task scores, we can present the user with the top training media that meet their requirements according to each of those considerations separately, or propose training media according to the highest level(s) of agreement between the two lists.

While these scores provide an immediate and useful metric for a user to consider what media may be most effective, they are not the complete story. In addition to the scores, one must also consider the possibility of a user selecting training tasks that are at odds with one another. One could imagine the scenario in which the ability to train on one task may have a negative impact on training of a second task, and is a factor to be considered.

4 Conclusions and Recommendations

Research into AR, specifically comparing outcomes to other training media, is not yet well-established in the academic literature. As such, the MERIT effort strived to organize and quantify the existing literature in order to create a standardized metric against which to measure the "goodness of fit" for using AR as opposed to – or in conjunction with – other forms of training media. Moving forward, it is the authors' hope that empirical research in AR focuses on quantitative analysis and comparison of factors such as those identified in the MERIT framework, so that the larger training community may attain increased benefit from the findings therein. An increase in evidentiary support for – or against – the use of AR in specific training scenarios will help ensure that the most efficient training can be deployed to the end user trainee in the most efficacious and advantageous way.

Further, the MERIT framework should be tested for validity to ensure that the framework accurately compares and contrasts training considerations to provide useful output for a training practitioner. The initial MERIT work also focused on completing a literature review of AR-based solutions for building the described theoretical framework and proof-of-concept algorithmic computations; it is recommended that practitioners continue to populate the MERIT framework and add theoretical findings available in the literature with respect to VR and traditional training methodology comparisons. In addition, and related to this recommendation, because the technology is constantly changing and evolving, and as such research will be (hopefully) continually conducted, the authors recommend creating a utility for training practitioners to continue to expand and build the MERIT framework and data set. This will ensure that MERIT maintains currency at the speed of innovation.

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Challenges in Creating a Mobile Digital Tutor for Clinical Communications Training

Wayne Zachary[4(✉)], Steven Bishop[2], Wally Smith[5], Janis Cannon-Bowers[1], Addison Blanda[1], Prathmesh Pethkar[1], Theresa Wilkin[1], Taylor Carpenter[3], Annika Horgan[3], and Thomas Santarelli[3]

[1] Starship Health Technologies, LLC, 2250 Hickory Rd, #150, Plymouth Meeting, PA 19462, USA
{jancb,ablanda,ppethkar,twilkin}@Starshiphealth.com

[2] School of Medicine, Division of General Internal Medicine, Department of Internal Medicine, Virginia Commonwealth University, Richmond, VA 23284, USA
steven.bishop@vcuhealth.org

[3] CHI Systems, Inc., 2250 Hickory Rd, #150, Plymouth Meeting, PA 19462, USA
{tcarpenter,ahorgan,tsantarelli}@CHISystems.com

[4] Starship Health Technologies, LLC, 1255 Tressler Drive, #150, Fort Washington, PA 19034, USA
wzachary@Starshiphealth.com

[5] School of Medicine, Division of General Internal Medicine, Department of Internal Medicine, Virginia Commonwealth University, Richmond, VA 23298, USA

Abstract. Doctor-patient communication is a crucial element in effective medical care, and the striking health disparities evident in patients with Type II Diabetes may in part be caused by physicians' difficulties in establishing effective communication with patients who differ from them racially, culturally, and economically. REPEAT (Realizing Enhanced Patient Encounters through Aiding and Training) is a digital tutor developed to help solve this problem. REPEAT teaches and coaches learners to improve their general and disparities-focused clinical communication skills using simulated encounters with computer-generated Synthetic Standardized Patients (SSPs) and augments experiential learning in virtual encounters by applying customized, context-sensitive, learner-focused scaffolding. REPEAT authoring tools enable rapid development of learning content, allowing economical transferability to other domains. Key human factors challenges and their design solution in REPEAT are discussed.

Keywords: Digital tutor · Clinical communications · Mobile · Game-based training · Intelligent tutoring · Health disparities

1 Introduction

Diabetes mellitus is a chronic metabolic disease that affects an estimated 29.1 million children and adults in the US alone [1, 2]. Type II Diabetes (T2D), the most common form,

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demonstrates striking health disparities in both health outcomes and healthcare quality, with minorities more than 70% more likely to be diagnosed and much more likely to experience complications [3]. Healthcare disparities have been linked, in part, to physicians' difficulties in establishing effective communication with patients who differ from them in terms of gender, age, race, ethnicity and culture [4]. Doctor-patient communication is a crucial element in effective medical care, and diabetes-related complications and poor health outcomes that are often attributed to *non-adherence* (or *non-compliance*)—e.g., failure to make lifestyle changes or follow physician recommendations—may be more accurately viewed as a doctor-patient communication problem [5].

Current medical training practices in communication skills and associated content—such as disparities-related communication competence—rely heavily on traditional didactic instruction, traditional apprenticeship (e.g., internship and residency), and the use of occasional simulated encounters with actors playing the patient role, commonly called Standardized Patients (SPs). Didactic instruction is unlikely to lead to long-term change in clinical behavior without follow-up practice. Apprenticeship allows the learner to observe and practice, but often without standards-based assessment. Live role-play with SPs, combined with individualized critique from instructors, allows for such practice, but is expensive, constrained by cost and availability of SPs, and not scalable to universal use.

A viable alternative to live SP encounters can be found in work associated with scenario-based training (SBT) [6, 7] and digital tutoring [8, 9]. SBT is an approach to experiential training that engages the learner in repeated authentic practice opportunities using state-of-the-art modeling and simulation technologies [10]. Based on extensive findings from the science of learning and human performance, SBT is based on the notion that expertise is developed as learners are exposed to many examples of a task or situation [6]. Using simulation for training in the more technical aspects of medicine (e.g., surgery) is quite common [11, 12]. However, use of simulation and scenario-based training in other areas of medical training has lagged, due in part to complexity in modeling human-to-human interactions. Digital tutoring, sometimes termed intelligent tutoring, takes the approach of SBT one step further by seeking to integrate a model of a one-on-one human tutor into the simulated practice environment. It does this by providing individualized in-practice instruction, in the form of coaching and feedback (and other forms of scaffolding) that is adapted to the individual learner based on a dynamically updated model of the state of the learner's acquisition of the targeted knowledge.

To address the problem of helping improve physicians' clinical communication skills in treating T2D patients who differ from them racially, culturally, and economically, we have developed a digital tutor called REPEAT (Realizing Enhanced Patient Encounters through Aiding and Training).

2 Key Human Factors Challenges in Designing REPEAT

REPEAT teaches and coaches learners to improve their general and disparities-focused clinical communication skills in treating patients with T2D. It provides didactic instruction, and then tutors learners' communication skill through practice in simulated encounters with computer-generated Synthetic Standardized Patients (SSPs). It enhances experiential learning in virtual encounters by applying customized, learner-focused scaffolding that is context-sensitive to learner actions. REPEAT authoring tools enable rapid and easy development/editing of learning content, allowing economical transferability to other clinical and even non-clinical domains.

There were multiple challenges encountered in the design of REPEAT. Some of these were specific to the clinical communications domain, while others were related to the problem of providing training (in general) and creating digital tutors (in particular) for inter-personal interaction and communications skills. And still others arose from underlying social and economic issues underlying health disparities. Below, we discuss five of these challenges, followed by a summary of how they were addressed in the design and development of REPEAT.

2.1 The Clinical Encounter Is Neither Symmetrical nor Necessarily Collaborative

The clinical encounter between health-care provider (typically a physician, though the two terms are used interchangeably here) and patient is a face-to-face interaction that largely consists of the two parties talking to each other [13], although neither in a casual manner (as in everyday conversation) nor in a structured teamwork manner (as in communications between an aircraft pilot and an air traffic controller). Rather, the interaction is highly purposive — specifically towards discussing the health of the patient, most often with regards to a specific health problem — and broadly structured by many factors, including the specifics of the health problem. While the purpose of the visit may be shared between provider and patient, however, the structure and dynamics of the interaction are asymmetrical and the goals of the interacting parties are frequently different and sometimes even divergent.

The asymmetry begins with the encounter setting. The encounter typically takes place in the everyday (and familiar) workplace of the provider, which to the patient is often an unfamiliar and uncomfortable setting, and frequently associated with emotions of discomfort or fear. The physician has more control than the patient has in establishing the agenda and flow of the interaction, and in controlling its pacing and termination. This can be perceived as a power differential, particularly for patients from low-income and/or marginalized populations, who often bring both personal histories and expectations of discriminatory interactions in situations where there is a high power-differential. At the same time, the physician may perceive having much less control over the content of an encounter than it would seem to the patient. For example, encounters must address certain topics and cover certain data points, or they either cannot be billed or will be marked as a “low quality” encounter. Such dictums and constrains are the result of large-scale policy, organizational, and economic forces that are beyond the control of the provider (or the patient).

The goals of the participants converge at the highest level on resolving the patient’s health problem, but at lower levels and on dimensions such as economics of the visit and the treatment plan, the goals of the parties can and often do differ. Patients, for example, bring goals and concerns to the interaction that reflect issues of their lives outside the encounter. These include:

- financial concerns, ranging from the cost of the treatment plan to the plan’s and the health condition’s impact on their ability to work and earn money; and

- social concerns, such as the patient's ability to fulfill internalized responsibilities to care for or provide for family members.

Again, when the patient is low-income or marginalized, the broader problems of limited access to education, employment, housing, transportation and even food, become intertwined with concerns about health and treatment [14] that affect the patient's goals for the encounter.

Analogously, the provider brings goals and constraints to the encounter that affect the structure of the interaction. These include concerns about the economics of daily workflow and the time that can be reasonably spent with each patient, regulatory and organization requirements and prohibitions, concerns for liability and litigation exposure, among others. Beyond these divergent goals and concerns, there are also underlying concerns about biases, implicit and explicit from providers, and expectations of bias (whether warranted or not) on the part of patients.

Together, the complexities of these clinical encounters for low-income/minority patients create a substantial challenge for crafting virtual encounters in REPEAT that can be both realistic and designed so as to provide a clear opportunity for development of improved communication skills on the part of providers.

2.2 Communication Skills Involve Diffuse Knowledge

The communications skills that are needed to improve clinical communications are themselves another challenge. Much of digital tutoring research has focused on problem areas in which the underlying knowledge is well defined and unambiguous its application (e.g., mathematics or physics problem solving, programming), e.g., [15]. However, the knowledge needed to draw out unexpressed patient issues and to adaptively apply that understanding of those issues in an encounter, certainly does not have these properties (or at least our understanding of the underlying knowledge is insufficiently advanced to be able to express in the same precise manner as rules of math of physics). Rather, the knowledge and skills needed are understood at much more abstract levels, in terms of constructs such as active listening skills or empathetic skills. Such abstracted skill definitions are not tied at all to specific knowledge elements that a learner must acquire and apply in order to acquire and improve those skills.

The vague definition of the skills makes them difficult to teach, difficult to learn, and perhaps most importantly, difficult to assess. These limitations, in turn, make it challenging to develop provider-SSP dialogs for REPEAT that lead to clear applications of the desired underlying knowledge and skills, that can be automatically assessed by the software, and that can be demonstrated to transfer to live interaction settings.

2.3 Patient Variability Drives the Learning Opportunities

There are many concerns and issues that individual patients bring to a clinical encounter, and that affect each patient's goals and approach in the encounter. To the extent that many of these concerns and issues are based on larger socio-economic problems, providers have to deal with similar problems and concerns repeatedly, but each time cloaked within the unique situation of each patient. Still, however, the specific factors that affect each individual encounter are unique to each individual patient and remain invisible with each patient until exposed through the dialog in the interaction, whether general (as in lack of insurance) or unique (as with an elderly dependent living in the patient's house). Once the relevant factors affecting that specific patient are made known, the provider must then be able to determine how each could and should be factored in that patient's treatment plan.

Since each patient brings both common and unique challenges, providers using REPEAT to develop and hone these skills through virtual practice need to have access to a sample of virtual patients that are, at the same time, realistic individually and representative collectively of a specific population. Developing such a sample of virtual patients with regard to a reference population and the health barriers which that population faces presented another challenge to REPEAT design.

2.4 Context and Flow Are Critical in the Interaction

Providing for appropriate and realistic variability across the set of patients that a REPEAT learner will encounter is important because that learner must develop communication skills that can be applied the full range of patients that she or he will encounter in the clinical 'real world.' But creating this variability in the virtual patient population is not enough by itself. The dialogs in the REPEAT encounters must also be designed and manipulated so as to allow for the unique set of concerns, health barriers, and constraints for a given patient—the patient's backstory—to affect the course of that dialog in a believable and appropriate manner. The patient's backstory contains elements of information that must be discovered by the learner in the interaction and recognized in terms of their relevance to the patient's treatment and self-management plan for the patient's T2D. Such details of the patients' backstory, once exposed in the dialog, then become context for future evolutions of the interaction, both for the physician and by the patient.

For example, consider a patient who is unemployed and does not own a car or live near public transportation. These are factors that can affect that patient's ability to afford additional medications or to travel to treatment sites (e.g., for physical therapy) that are not very near to her home, but the patient may not expose this information spontaneously to the physician. Instead, the physician must use learned communication skills to probe and identify the existence of such barriers, exposing these as elements of context for the encounter. Failing to apply those skills successfully would leave those issues unexposed, and leave the learner unable to tailor the treatment plan to the exposed context elements. Additionally, even if exposed, the learner might remain aware of these context elements at that later point in time and still fail to appropriately use this exposed context information in the treatment plan development. Further, in this latter situation, the patient may become upset or discouraged at what is perceived as the physicians not caring about the information, or forgetting it quickly. These feelings can then negatively affect the patient's participation in the dialog going forward. For REPEAT to be effective, the dialogs within the virtual encounters need to be constructed or controlled in a way that ensures that all such context-sensitive evolutions are available.

2.5 Natural Language Interaction Is Not (yet) and an Option

The ideal form of the dialog in a REPEAT virtual encounter is through unconstrained spoken natural language. This is the mode of interaction that the learner will use in live encounters, and one that should create not interactive 'friction' between the learner and the digital tutor. However, the reality is that the current technology is not yet close to being able to support this form of interaction, for multiple reasons. These include the need for virtually 100% accuracy in recognition, the need for completely understandable computer-generated speech, and the need to be able to construct extended robust dialogs that are based on the unique backstories of different simulated characters. None of these is within the capabilities of the current state of the art (see [16]). Thus, the complex constraints on the provider-patient dialogs described earlier in this section had to be met with more constrained approaches to the verbal interaction.

3 Design Solutions in REPEAT

The design for REPEAT addressed each of the challenges and issues discussed above. Because REPEAT is, above all else, an instructional system, the highest level design decisions concern what specifically would be the learning objectives and how learner progress against those objectives would be assessed. These decisions were informed by developments resulting from the increased concern with clinical communication in the 21st century (see [13: preface to 2nd Edition]) in research, policy and medical education communities. Of main relevance to the development of learning objectives were the Core Entrustable Professional Activities (EPA) for Entering Residency (CEPAR) developed by the Association of Academic Medical Colleges [17]. EPA 1, "Gather a history and perform a physical exam", was used as the key integration point between REPEAT and CEPAR along with four specific competencies required for developing cognitive and communicative skills necessary to EPA 1. The four specific competencies were then tailored to the REPEAT focus on low-income African American T2D patients. From this basis, learning objectives were then defined from these desired competencies, from using the Reporter-Interpreter-Manager Education (RIME) model in medical education [18, 19], where new learners are expected to gather and report information accurately and more advanced learners are expected to educate patients and other learners. Three specific curricular units were also defined, corresponding to the three RIME level (R,I,M/E).

For the assessment of skills on these objectives, an independent measurement scale was used and adapted for both assessment of behavior against the learning objectives within a virtual encounter and in live encounters, thus providing a common measure for instructional assessment and transfer of learning assessment. This was the Macy Communication Scale for provider-patient communications [20]. As with the RIME-based objectives, the MACY-based assessment scale had to be adapted to the health disparities context of the curriculum. One further extension of the assessment scale had to be developed as well, that of support for encounter authoring. The creation of encounter scripts (discussed below) required the definition of choice points in the encounter where a learner needed to chose a path forward from among finite options.

These choice points were linked with learning objectives (one or two per choice point), with different options representing positive or failed application of the skill associated with the learning objectives. The relevant elements of the MACY-based within-encounter assessment scale were, in essence, reverse engineered to provide guidance to the choice-authors on how to craft choices that were either good or bad with regard to each applicable objective. This guidance helped authors create choice options that were both consistent with the objectives and with the assessment scale.

The problem of creating a realistic and representative set of patients for the REPEAT practice encounters was addressed using a method called Backstory Elaboration [21] created earlier in REPEAT development. Backstory Elaboration uses a structured process, informed by social/behavioral science data on the population being represented, to create a set of characters with individual and unique backstories. Each backstory includes specific values from relevant socio-demographic, medical, and psycho-social variables that are also integrated into a narrative that is the literal backstory. The backstory narrative and set of specific variable characteristics were then used to create an appropriate on-screen avatar for the character, and were used to build out the dialog for that patient in a specific encounter.

The remaining design challenges all concerned the representation and engineering of the provider-patient dialog within a given encounter. The encounter dialog had to support the structural constraints required by the medical purposes of the visit, allow substantial openness in the possible evolutions of the interaction given the patient's backstory and the context factors that they afforded, and allow the full range of knowledge and skill that the learner could employ in conversing with the patient. The dialog also had to be engineered to offer options to the learner that could be effectively mapped into learning objectives and could change depending on the degree to which the relevant patient context was successfully exposed. Plus, as noted above, it could not rely on open-ended natural language interactions.

The design decision for this key aspect of REPEAT was to represent each encounter as a network of possible dialog transactions. The dialog nets were designed around a basic dyadic turn-taking transaction as a fundamental building block – a simple ordered pair of "character 1 says something and character 2 says something back" – and multiple layers of structure. At the most abstract level, the dialog was structured into segments that created a macro workflow for the encounter. The workflow was defined by the type of the encounter, (e.g., initial diagnosis of T2D, follow-up visit for a diagnosed patient, follow-up visit for diagnosed patient with a specific type of complication, etc.).

Within each segment, the next layer of structure added the dialog details. A dialog flow was created within each segment as a combination of linear sequences of transactions and choice points for the learner. The choice points were created at points in the dialog flow where the learner had to apply (or fail to apply) specific knowledge and skills to the choice of the next thing to say to the patient. Each choice point was linked to one or two learning objectives for the specific unit of the course, and structured to pose different combinations of success/failure on the linked objectives (e.g., for two objective there could be a +/+ option a +/- option, etc.). The specific dialogs for each option were authored using the objective-anchored authoring guidance discussed above. The branches created by the options could continue through the current segment or even branch further, but had to be reunited at the transition to the next segment of the encounter.

At the next level of structure the learner assessment was added. When a learner made a specific decision at a choice point, the objective ± ratings of the chosen option were provided to the REPEAT student model. That model kept a dynamic estimate of the leaner's knowledge state on each objective, and updated it after each learner choice. It then used that updated estimate to determine which form and content of scaffolding (e.g., level of feedback) was appropriate for that learner given the just-made choice.

Thus the dialog network structure allowed flexibility and variability and linkage to assessment and scaffolding, as desired. However, the basic dialog network became a stateless process at each convergence point at the transition from one segment of the encounter to another, and therefore had no way to deal with exposed context information or to propagate it forward. This capability was added at the final level of the dialog net using a novel method. At this level, context metatag information was attached to specific utterances within transaction nodes on a dialog tree at which context information was exposed into the dialog. The metatags identified the specific context information exposed, and were organized according to the variables that were included in the patient's backstory (as established in the Backstory Elaboration analysis). The metatags were processed by a novel component of REPEAT called the context cart. Like the shopping cart in an e-commerce app, the context cart collected information that could be passed forward to future steps in an otherwise stateless process. Thus, if a piece of context were exposed in a specific patient dialog utterance, its metatag would be placed into the context cart. At later points in the encounter, the presence/absence of that piece of context could be detected by REPEAT, and used in customizing the choice options, e.g., by presenting or hiding specific dialog options.

A virtual encounter in REPEAT could therefore be represented in single complete dialog network. This full dialog network was then translated into a data structure that could be used by a computer game engine to express the encounter as an on-screen game that paused for learner input at each choice option point reached, and provided customized adaptive tutoring information as provided by the REPEAT student model that worked in tandem with the game engine.

One final decision in REPEAT was the mechanism used to deliver the training. Virtually all prior virtual tutors and simulation-based training had been designed for delivery on a desktop or laptop computer. However, we wanted to make REPEAT available for anytime, anywhere usage, and the end-user analysis of our target population (medical students and residents as well as practicing physicians) suggested that the device that was constantly available was neither a laptop or desktop machine, but rather a smart phone. Thus, we developed REPEAT to be entirely accessed through a learner's smartphone.

4 Overview of the REPEAT System

The heart of REPEAT is the REPEAT app, through which a learner accesses REPEAT courses. This app can be downloaded in any Android or iOS smart phone or tablet. The app itself is built using the Unity 3D game development toolset, but within that app all the elements of tutoring – learner modeling, management of scaffolding to the learner based on the curriculum and the specific learner's modeled knowledge state, and context management – are done through an embedded subsystem built outside of Unity 3D. In comparison, the main UNITY component processes the script for the encounter as an interactive game, and controls input from and output to the learner, both within a practice encounter, and outside the encounter. The outside-the-encounter functionality includes selection and execution of specific courses, course units, and practice encounters within a unit, as well as access to didactic instruction at the course-unit level. It also includes access to and presentation of displays on the learner's progress through the curriculum, by objective.

When the learner accesses a course, the course material is downloaded from the REPEAT back-end server onto the learner's device, and the learner can access, leave, and return to the app at any time. As the learner progresses through specific units, and takes part in virtual practice encounters with different simulated counselees, data on the learner's performance is sent to the REPEAT back-end server for storage and analysis. Simultaneously, the virtual tutor within the app provides the learner with scaffolding (forms of instructional support) designed to improve and shorten the leaner's time to achieve competence in each skill taught by that course.

The REPEAT back-end services also support interaction with and manage access to various databases with the learning materials (e.g., course structure, didactics, practice scenarios) for each REPEAT course, and with all the performance state of each learner on each course, as defined by the most recent of the student model for that learner/course combination. Performance data on each choice made by each learner in each course offers the opportunity for more fine-grained analysis of learner progress as well as of the diagnosticity of specific choice-points across learners. Each such selection can be viewed as an individual learning experience [22] that can be captured as such and stored in a Learning Record Store system (LRS) [23]. REPEAT includes mechanisms to capture learning experiences and to export them to an external LRS. Existing LRSs 'both research and commercial' contain instructor-facing tools to analyze learning experience data.

The back-end services can also communicate with the Learning Management System (LMS) of a specific institution or organization, allowing that institution to authorize specific learners access to the course, and to receive each authorized learner's final performance data after course completion.

The learning materials, such as the objective structures, patient backstories, and the encounter scripts are created through a separate set of REPEAT Authoring Tools, via a web-based user interface to the REPEAT back-end services. The Authoring Tools also allow existing courses to be edited, extended, or 'cloned' as the starting point for new courses.

Finally, the back-end also provides an in-process web-based dashboard for training instructors or managers, allowing those individuals (authorized by the institution) to view individual learners progress data at a range of level of aggregation. This supports, for example, opportunities for blending the virtual learning with live classroom learning and discussion. Figure 1 depicts the logical architecture of the current REPEAT System.

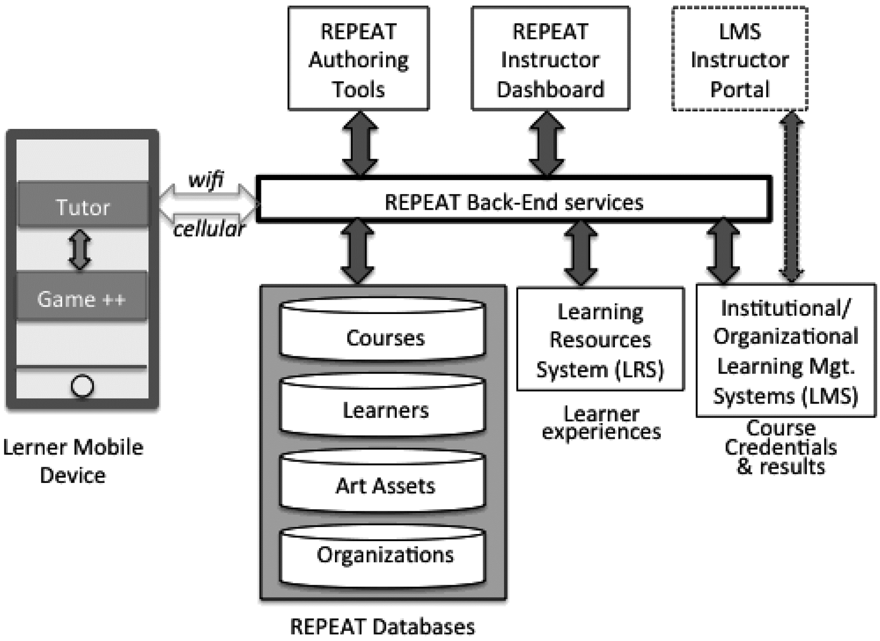

Fig. 1. Logical components and interconnections comprising the REPEAT system. The dashed lines around the LMS instructor portal indicate that it is a functionality provided by the local LMS and not from REPEAT.

5 Summary and Future Research

REPEAT (Realizing Enhanced Practice Experiences through Adaptive Tutoring), is a digital tutor designed to improve physicians' clinical communication skills in interacting with T2D patients from low-income minority populations. It does this by:

- allowing them to practice these skills in simulated encounters with computer-generated virtual patients, and
- guiding their virtual practice with customized, learner-focused scaffolding that is context-sensitive to learner actions and inferred skill level.

REPEAT was designed to deal with a range of challenges arising from the specific content-area, plus additional challenges associated with the need for anytime/anywhere access to practice and tutoring (which resulted in the delivery of the REPEAT curriculum through a smartphone app). Key content-domain challenges explicitly addressed in the REPEAT design include:

- participants in clinical interactions bringing overlapping (but not converging) and sometimes diverging goals to the interaction;

- incorporating the large variability in individual issues, histories, and concerns on the patient side that must be represented across practice encounters to give the learner a reasonable range of experience from which to learn;
- creating interactive sessions that can evolve in complex context-sensitive ways; and
- circumventing technology limits precluding the direct application of open-ended natural language processing technology.

These challenges are also common to other communications and 'soft skill' content domains, making the REPEAT approach and training delivery technology more broadly applicable. Current research is underway to assess the training efficacy of the REPEAT app and disparities communication curriculum, through a randomized control trial with graduate and undergraduate medical students. Futures research areas involve exploring the component and comparative value of different features of the training delivery design.

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“Step into the Future” Program as a System of Non-formal Research Education in Russia

Alexander O. Karpov(✉)

Bauman Moscow State Technical University, Moscow, Russia
a.o.karpov@gmail.com

Abstract. The purpose of the study is identification a role of the human factor in the development of the “Step into the Future” program, that has played a decisive role in transformation of the Russian educational system; theoretical development of epistemo-didactic concepts characterizing the educational activities under the program. Educational features that indentify its originality and development are explicated in the pre-history of the “Step into the Future” program founded in 1991. Humanistic missions of the program team are defined and educational strategies of the program are described. The intentions of the fundamental epistemo-didactic concepts of research education cultivated by the program are revealed. The conclusion is made that the human factor plays a decisive role in the development of modern education systems, and not only as an instrument for overcoming conservative traditions, but to a much greater extent as a creating source.

Keywords: Human factor · Non-formal education · Research Knowledge society · Didactics · Generativity · Learning · Environment

1 Introduction

The present-day society sees the horizon of its existence through the paradigm of knowledge society, where knowledge is able to create things, technologies, global and local structures of life, human relations. But who creates this society? In fact, it is not just knowledge, but people through whom it acts and who, finally, act by means of it. The fundamental basis of this society is a human factor manifested itself through creativity of a special research type.

The knowledge society reality was becoming apparent from the mid-XXth century. A new system of labor division emerged in those days, where a knowledge worker played a key role. In 1957, Drucker talks about the development of an innovation system that includes science, as well as a pluralistic society of organizations and a society which is based on education [1]. In 1999, Bell points to powerful science-driven research universities, strong entrepreneurial culture and venture capital for small business financing as sources of the US technological leadership [2]. Science is increasingly becoming a single source of additional knowledge, and knowledge is positioned as a new axial principle of the society [3].

The knowledge society relies on cognitive abilities of a creative personality [4]. Cognitive-type professions are becoming instruments of material and spiritual growth

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of the society [5]. Education that trains young people with capacities for scientific creativity and innovation activities, i.e. *research education,* is playing the role of a culture-producing basis of the knowledge society [6]. The research education is aimed at complex high-level competencies and starts from school years [7]. Early engagement of promising schoolchildren in research activities at the age of 11–13 years is of key importance [8].

Formal school, olympiads and traditional project activities can't develop scientific-type research behavior, scientific methodicalness of the mind and skills of scientific-research cognition [9]. They can't develop the main thing any scientific research activity starts from - the ability to see the problem, comprehend it and identify the subject of study or development. Conditions, in which olympiads or a school project occur, form a thinking model that is not authentic to research activities in science and engineering. The formal school trains future knowledge workers in conceptual categories of Descartes, Newton and Laplace, whereas the modern scientific thinking operates in the epistemic system of Bohr, Heisenberg and Prigogine [10].

In Russia, the development of a modern schoolchildren's research education model is a result of the "Step into the Future" program - the non-governmental and non-commercial initiative of scientists, teachers and education experts.

2 Objectives, Methodology, and Research Design

Objectives of the study: (1) identification the human factor role in the development of the "Step into the Future" program, which has played a decisive role in transformation of the Russian education system; (2) theoretical development of epistemo-didactic concepts defining educational activities under the program.

The methodology of the study in its first part includes: a review of documentary sources from an archive of the "Step into the Future" program as well as a personal archive of the author, who is the founder of this program; generalization and social-epistemological analysis of the historical material in terms of the human factor. The theoretical part of the work uses methods of an epistemo-didactic analysis and generalization of cognitive situations, a cognitive psychology, a structural-functional analysis of a social action, a philosophical ontology.

The research design determines the structure of this paper. At the first stage, educational features of the "Step into the Future" program prehistory, that determines its image and development, are explicated. Further, conceptual views on the role of the human factor in the development of the "Step into the Future" program are elaborated. At the second stage, the epistemo-didactic principles the program followed in its advancement are identified and analyzed, and they are conceptualized.

3 Results of the Analytical Study of the "Step into the Future" Program History

3.1 Pre-history of the "Step into the Future" Program

Before the beginning of the 1990s, the system of scientific work with young people was underdeveloped in Russian schools. Professional practices of schoolchildren were, as a rule, related to the sphere of blue-collar jobs and included an acquisition of simplest instrumental skills, e.g., for electricians, locksmiths, plumbers, etc. on the basis of vocational training centers. More often than not, engineering modeling was a construction of copies (dummies) of one or another technical device that gave only a net impression about an appearance of the technical object.

The "Step into the Future" program was founded in 1991 at the Bauman Moscow State Technical University (BMSTU). The program adopted traditions of the "Russian Engineering School" established at the University in the second half of the XIX century.

The history of the "Russian Engineering School" was associated with pedagogical innovations in the days of Nicholas I – the Russian Emperor, who recognized the education process organization as the most important state affair. One of specialized schools established that time was the Vocational School at the Moscow Foster Children House. Later on, it was transformed into the Imperial Moscow Technical University (IMTU), now – the Bauman Moscow State Technical University (BMSTU). The Regulations for the Vocational School (1830) set the task of making pupils useful members of the society by training skills for proficient craftsmen who possess theoretical knowledge, know the latest technical innovations, and can spread them.

In 1873, at the World Exhibition in Vienna, the "Russian method of craftsmanship training" cultivated in the IMTU awarded the Grand Gold Medal. Training of engineers by the "Russian method" gained widespread acceptance in other countries. G. Runckle, the President of the Massachusetts Institute of Technology (MIT), wrote that Russia achieved unconditioned success in solution such an important task as technical education and from then on, no other system would be used in the USA. Today, MIT is one of the best research universities in the world. The BMSTU gave many creators to the world, among them were designers of a helicopter, a diesel locomotive, a wind tunnel and a passenger jet, an automatic machine line, and a TV tube. Mankind stepped into space from inside the Bauman University.

3.2 Human Mission of the "Step into the Future" Program

In the early nineties of the last century, Russian society experienced radical socio-political transformations. The education system was subjected to economic repressions in conditions of total disinterest of political groups struggling for power.

In 1991, at the peak of social and economic reforms, when most residents of the country were interested only in problems of survival and subsistence, a small group of enthusiasts reflected on the role "the children of reform" would play in the forthcoming movement of Russian society toward human well-being and right forms of social life.

So the idea of the program and its name "Step into the future" were born, where an appeal not only to young generations, but to the total society could be heard.

On the vast geographical area, where more than 180 ethnic groups live, the "learning through science" educational concept was implemented that created effective social lifts for children from poor segments of population and godforsaken places. Against the backdrop of the economic downturn, voices of team members, their arguments and humanistic appeals were heard both in the country and abroad. They were able to concentrate material and financial resources and arrange new education activity in such a way that only talent and personal success became a condition for new prospects, regardless of social belonging.

Those children, whose destiny was predetermined earlier by a low social and cultural status of their families, at last have chances for education in best Russian universities; they receive scientific tutors and support from the "Step into the Future" program. The "iron curtain" that surrounded Russia falls for these children only now. For them, there are real opportunities for direct communications with their young colleagues from abroad. International scientific and educational events the program team organizes in Russia create these opportunities. Thanks to foreign partners of the program, today the best learners are able to attend scientific conferences and exhibitions in other countries, take part in scientific training at research centers. Thus, a new open youth community is formed in Russia, where children from different sociocultural strata united by common "research" lifework become its members.

The program team gives the top priority to training young researchers from schoolchildren who are focused on creation the new in engineering, natural-scientific and social-humanitarian knowledge. Only in a decade, Russian politicians began to talk about the knowledge society and innovative economy from a practical point of view. But by this time the "Step into the Future" program has already brought up a highly professional cohort of a new generation for our country – the innovation-minded young people. For comparison: only 72 schoolchildren came to the first polytechnic colloquium, today more than 150,000 schoolchildren and students take part in the "Step into the Future" program every year.

The program team completed the most difficult task as pioneers in the new education activity in view of enormous geographic sizes of Russia and its cultural diversity. The team members organized research training for schoolchildren and trained their followers in taiga jungles of the Far East, in mountain villages of the Elbrus region, in subtropics of the Black Sea region, in polar deserts of the Russian North. Schoolchildren and teachers gained practical experience in improvement of their life and life of surrounding persons with the help of science. Often, research training took place in multicultural groups with participants from different ethnic groups. In this way science instilled tolerance in children and taught how success could be achieved together.

Vast areas in Russia, where there were no universities and research centers, became frequently visited by scientists and professors to bring up worthy successors of their work. Schoolchildren were not only keen on scientific solutions of problems, they began to travel to their young colleagues and tutors. A special motivation was required for this purpose, considering that sizes of Russia from west to east were a quarter of the Equator length. Thus, the "Step into the Future" program promoted widening of ties that consolidated the country, while politicians sought to separate it.

For children from "Russian humble beginnings" (Russian poor families) – and they were the majority of the country's population – a new social lift appeared that gave a way for talents to intellectually privileged spheres of life: engineering, science, medicine, and art. Indeed, and in art too, because the program team was an initiator of the first National Festival of Young Couturiers and Designers in Russia, which has been patronizing since then the most authoritative higher education institution in this area - the Moscow Textile University.

It is surprisingly but the fact that the activity based on exclusively altruistic and ideologically not engaged principles, in conditions of economic distress, complete indifference from the party of financial tycoons and a political group that took power, had such a significant social effect that subsequently became a model for many state and public initiatives.

3.3 Educational Strategies of the "Step into the Future" Program

The "Step into the Future" program team developed and implemented an effective territorially-distributed system of research education for schoolchildren. Its main link is a scientific-educational partnership organized in the form of a coordination center. This partnership unites schools, universities, scientific institutes, high-tech enterprises, cultural organizations, and innovative development centers. The area of its geographical responsibility can be a small settlement or a big city, a small rural district or a region larger than the Europe. The initiative to create the first coordination center was announced in 1994 in Usolye-Sibirskoe, the small taiga town. By 2000, this center united enthusiasts across Siberia; the Siberian Branch of the Russian Academy of Sciences is cooperating with this center; it holds the main scientific youth forums of this huge region.

By 2005, the research type educational network created by the program covered the total territory of the country – from the Pacific coast in the east to Karelia in the west, from Murmansk in the north to Dagestan in the south. Research and development activities were organized in the form of youth scientific laboratories, design bureaus, forest ranger stations, agro-sites, startups and innovative enterprises.

Scientific-educational partnerships have become a place for diagnosing creative abilities and psychological support for young researchers. They gave opportunities for talented schoolchildren and students to carry out their works on the basis of research laboratories at universities and scientific institutes, in engineering centers and workshops of high-tech companies [11]. Thereby, problems of accessibility of an expensive scientific-technical base, advanced scientific methods, and assistance from highly professional tutors were solved. With the program support, young researchers began to apply for patents and open scientific businesses.

In 1995, the program established the Russian Youth Polytechnic Society. In 1997, it organized and successfully held the "Youth-Science-Business" innovation contest for the first time in Russia. In 1998, it developed a national network of youth scientific and engineering exhibitions. First exhibitions were held in Moscow, Lipetsk, Murmansk, Nalchik, Chelyabinsk, Usolye-Sibirskoe.

In 2010, the program launched the first large-scale project of research training in Russia for the *most promising and exceptional talented* schoolchildren. The project was called “Scientific staff for the Future”. At the territory of the country covering all nine time zones, young people at the age of 11–15 years were screened throughout the year. Robotics, ground and space transports, intellectual systems, biomedical engineering, nanotechnologies, and energy systems of the future were chosen as research training areas. Upon completion of training, participants of the “Scientific staff for the Future” project continue their research activity as members of professional teams of scientists and designers of new technologies.

In 2011, the “Innovative Future of Russia” project was launched. The project was aimed at developing skills of scientific entrepreneurship for schoolchildren and students of introductory courses having inventions in the field of science and technology. The project received support from the Ministry of Economic Development of Russia. In 2015–2016, the methodology of scientific training for talented children from needy families, children with disabilities, and children in extreme circumstances was developed and tested.

Today, the “Step into the Future” program is a joint work for many people and various organizations. It is an authoritative nationwide movement that unites scientists, teachers, lecturers, specialists and forward-looking politicians in matters of education of innovation-minded young people focused on creation of scientific innovations, advanced engineering, and high technologies. The program acts as an inter- and trans-disciplinary research site, where a huge fund of knowledge, talent and energy is concentrated and which is a strategic resource of the Russian society in its movement towards human well-being and right forms of social life.

4 Results of Theoretical Conceptualization of Educational Activities Under the “Step into the Future” Program

4.1 Basic Conceptual Statements

The analysis of the more than 25-year educational activity under the “Step into the Future” program made it possible to formulate the following conceptual statements.

In modern society, research education acquires its methods, environment and forms of institutionalization, becoming a *special* part of the educational system responsible for upbringing a group of technological progress. It requests scientific-cognitive continuity between secondary and higher schools. For secondary education, this means that it becomes *non-general and non-universal*. For research universities and innovative science, this shows their growing dependence on cognitive ability of a schoolchild to master complex systems of *modern* scientific knowledge [12].

Research education becomes an instrument of research-type socialization, that makes young people ready for life in the knowledge society [13]. This new type of socialization, first described by me, achieves a global cultural importance. Research education gives a dynamic competence to a growing personality that enables to foresee a direction of changes in the content and configurations of professional knowledge, predict in-depth cognitive transformations of the paradigmatic type [14]. A new type of ascending mobility or cognitive mobility as I call it is being formed by means of research education. It performs the function of social distribution of learners according to their cognitive vocation in the epistemic structure of the knowledge society, i.e. it provides an ascending movement towards the professional cognitive-type environment depending on abilities of thinking and mental structure of a personality [15].

4.2 Generative Training, Environment, and Generative Didactics

The fundamental epistemo-didactic characteristic of research education is its *generativity*, which I define as an active source creatively stimulating to cognition, creation of new knowledge and its social-economic application. The generativity property extends to both education and learning environment.

Generative training is aimed at developing capacities for discovery new knowledge and methods of its transformation [16]. It involves not only processes leading to scientific creativity, but also formation of a special value system, peculiar to epistemic communities (e.g., in respect to search for the truth, partnership, and competition), scientific-type research behavior [17], scientific cognitive trajectories of personality development (problem-cognitive programs) [18]. The generative training, cultivated by the "Step into the Future" program, is based on method of scientific researches [19].

The generative nature of education manifests itself in the approach to on-going appraisal of a learner. Conventional appraisal based on a correlation between learner's outcomes and established standards can't be a measure, to a large extent, for products the learner created independently. In generative (not just summing up) estimations, a special focus is made on *what* the learner can make with the acquired knowledge, and not how well acquired knowledge match with the boundary set by others [20]. It is worth noting that competencies answer the question "*how* does a learner operate with knowledge?"

The generative learning environment is a combination of cognitively active forms of cognition organization and a special cognitive operationalism they contribute to learning practices. The generative learning environment contains uncertainties that stimulate imagination. They are contained in those problems that are solved or can be set in it. The problematic situations it offers give a material for a choice of a cognition object and its comprehension. Thereby, they structure cognitive activity. Collectives of people engaged in professional work with knowledge demonstrate patterns of search activity. Along with the fact that this environment "leads" into researches and developments, it contains authoritative truths and rigid epistemic models to be overcome in the process of searching for new knowledge. In this way the generative environment teaches to strive for scientific truth.

The research training theory developed by me is called *generative didactics*. It proceeds from foundations of the education structure in the knowledge society and analyses the method, environment, knowledge, and cognition from the viewpoint of education and upbringing a personality capable for creation and materialization of knowledge, i.e. for transformation of knowledge into technical and social objects and technologies.

4.3 Method of Scientific Research

The method of scientific research was conceptually developed by me as an instrumental core of the research training system under the "Step into the Future" program. From the mid-nineties, the method of scientific research in various forms is used in Russian secondary and higher educational institutions cooperating with the program.

The method of scientific research is a cognitive tool of research training that didactically uses the methods of scientific search with the aim of personality becoming through the study of oneself, the world around and oneself in the world. The essence of the method of scientific research is social and existential training in formation a person engaged into the scientific-cognitive attitude to the world. The method of scientific research solves the following key tasks: *pedagogical task* – upbringing a researcher; *epistemic task* - formation of a scientific-research complex of knowledge and competences; *ontological task* – development a special attitude to the truth that determines the scientific-type research behavior.

The method of scientific research builds up learning as a *continuous* research "project" forming a knowledge complex of personality in the spirit of research that creates a problem-cognitive program for an individual. The method is not so much used for verification of class-lesson knowledge and their social "revival" as it is aimed at mastering the scientific methodology. This "methodological" training is focused, first of all, on present-day and future professional interests of an individual. It is from this perspective the methods of knowledge acquisition are mastered, and general and special competencies are generated.

4.4 Innovative Environment and Creative Space

In general, the generative learning environment is defined by me as an educational system that stimulates and shapes the creative function of thinking, and possesses required socially active cognitive components. This very general theoretical construct sets a framework description.

Analysis of the generative environment as a structurally intricate epistemic *surrounding* leads to cognitively constructional concepts. Thus, the "learning and scientific innovative environment" model developed by me for Russian schools and universities can be interpreted as an epistemic mega-kit containing such components as research groups, business incubators, small innovative enterprises, scientific societies of learners, technological consortia, generalized knowledge funds, etc., distributed and classified at a structural-functional level and a meta-level [21].

By making an emphasis on the ability of the generative environment to be a creativity initiator, i.e. making accent on the cognitive-operational function, I arrived at theoretical vision of this environment as a creative space and defined it as follows.

The creative space is a cognitive-generative system stimulating creativity and development processes of the creative thinking function via a link of cognitive activity with an epistemically active (generative) environment. This definition assumes that creative spaces should be socially-saturated and creatively stimulating for cognition; they should actively operate as a factor in creation of scientific and technological innovations, as well as take an active part in processes of their practical application promotion; i.e. be generative in their structure and functions. They should function as a single epistemo-didactic complex, whereby the education becomes a direct actor of a social action aimed at the knowledge society development [22].

5 Conclusions

The human factor plays a decisive role in the development of modern education systems, and not only as an instrument for overcoming conservative traditions, but, to a much greater extent, as a creativity initiator. The public initiative has advantages over formal directives and, above all, in attitude toward matters, which is expressed in unconditional pursuing the truth both in creation of new organizational forms of education and in pedagogical practices. As a result of searching for the truth, theoretical developments describing non-formal social activity give an option to take a look into the future of education, and thereby create beacons for its authentic transformations.

The "Step into the Future" program provides an example of this social and theoretical effectiveness. At the World Innovation Education Summit (WISE, Doha, 2011), the "Step into the Future" program was recognized by the international community as one of two primary innovation projects in Russia. As a result of independent monitoring, only two Russian projects were invited to the summit – the "Step into the Future" program and the Skolkovo center. In such a way the initiative public project ranks alongside with the financial empire with the amount of investments making a sizable part in the country's budget.

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Crucial Moments in Professional Careers of Preschool and Primary Teachers

Adriana Wiegerova(✉) and Hana Navratilova

Faculty of Humanities, Department of School Education, Tomas Bata University in Zlín, Zlín, Czech Republic
wiegerova@utb.cz

Abstract. The aim of this study was to describe the development of preschool and primary school teachers' careers from their perspectives. Theoretical part of the study summarizes the knowledge about the teacher's profession and the periods of teacher's career. Regarding the development of preschool and primary school teachers, the authors considered the relevant differences between them. The goal was to find out the principal differences in teachers' careers with probable origins and impact on teacher training programs at the university. The empirical part presents the results of qualitatively oriented research. The research data was obtained through twenty in-depth interviews that were conducted with teachers and kindergarten school directors, teachers and head teachers at primary schools. By analyzing and processing interviews, the categories capturing the teacher's career paths were identified. Crucial moments in the course of teachers' carrier development are discussed as fundamental, specifically in case of female teachers after becoming a mother. Other identified crucial moments include getting the position for a director or losing a job. A comparison of data from preschool and primary school teachers shows that preschool teachers enter faster into the phase of stagnation in their career development. The processing and evaluation of obtained data led to the creation of a theoretical model of the career path of preschool and primary school teachers.

Keywords: Teacher professional career · Primary school teacher Preschool teacher · Teacher professionalization · Crucial moments

1 Introduction

This study focused on the professional career of preschool and primary teachers. Based on the theory presented by Day et al. [1] professional career is considered as a person's progressive development through the whole life. The concept of career is often misunderstood and limited to be viewed only as an individual career. A career may have either a progressive or a regressive trend. According to Šnýdrová [2], career is always assessed on the basis of certain criteria, namely: the job position in which the individual is staying, salary level, material benefits, number of subordinates, extent of responsibility, decision-making powers and others. Professional career has different specifics. It differs into two elementary dimensions: (a) objective (b) subjective.

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The subjective career reflects on the individual, subjective interpretation of a career, on subjective interpretation of objective and subjective data, on subjective meanings of the objective career. The objective (or external) career is formed by the judgment of others and recorded in personnel documentation. Basically, we can consider four professional career periods. The preparatory period takes up on the first commencement of employment. Career start-up period is defined from the first commencement of employment to approximately age of thirty-five. The next period is a middle-aged career, lasting from about thirty-five to age of fifty-five years. The last career period of the older age is defined from the age of fifty-five years and it is typical for this stage to pass experience through mentoring or coaching of younger colleagues.

There is a different perception of professional career at each level of education. This evidence is supported by comparing the status of preschool and primary teachers in this study.

2 Methodology

We suppose that relevant differences exist in development of professional carrier of preschool and primary teachers. The aim of the study is therefore to present the crucial differences in the professional careers of these teachers, so why they arise and how it can influence the training of future teachers at universities.

2.1 Research Method

According to our aim of the research, we decided to use the method of deep interview. We recorded each interview on the voice recorder and then transcribed into text. The following transcriptional rules were used in this research:

1. Accurate and verbatim recording of verbal speeches - the speakers 'and participants' own speeches, including incomplete words and repetitive words (so-called self-corrections);
2. Appearances of "mhm" and hesitation ("er");
3. Speech interruption longer than 3 s ("…");
4. Laughter ("laughter");
5. Incomprehensible sections caused by poor pronunciation, excessive noise, etc. ("incomprehensible").

This transcriptional system has proved to be acceptable and fully functional for the following analysis. The data analysis was based on so-called recursive reading. Repeated reading of the interviews enabled to permeate gradually into the ideas and opinions of the participants. This process resulted in a summative picture of the participants' statements aspiring to understand the interview as a whole complex.

Already during the first reading, the possibility of denotation or immersion in the data appeared. Subsequently, incoming interpretative ideas were recorded, the relevant sections identified, the context found. Gradually, the jottings were created for the next steps of data analysis [3].

The principle of induction was used in the research. The benefit of this principle was the emergence of a potentially new view of a research phenomenon. When reading and writing a transcript, the essential segments of the transcript were identified first. They provided relevant information and they were marked - coded. Segments were of varying length. These codes have been systematized and grouped according to their significance and then ranked hierarchically. The result of this procedure was to reveal the basic categories, which we described then in a descriptive way.

2.2 Sample

Twenty teachers from the Czech Republic including five preschool teachers, five primary school teachers, five heads of primary schools, and five heads of preschools created the research sample. The participants were chosen deliberately. The participants were middle-aged teachers who were contacted by phone. The personal data of the participants were also presented in the research so for anonymity reasons, the fictional names and abbreviations such as UA, UC were used instead of the participants' names. In addition, places where the teachers lived or worked were not included in the text. Informed consent was submitted to the participants prior to the interview. By signing the agreement, the teachers confirmed their participation in the research.

3 Findings

We discuss the data obtained through in-depth interviews with preschool and primary school heads and teachers in the following part of this study. The data were divided into three categories that emerged from the analysis and became significant in terms of professional career development of preschool and primary school teachers.

3.1 Becoming a Teacher (Professional Beginning)

The reasons why the teacher decides for this profession can be various and highly differentiated. The decision to become a teacher is preceded by many procedures, obstacles and developmental stages of an individual. Frequently mentioned teacher motives for this profession include, for example, the desire to work with children and to work for the younger generation; to do creative work; wishes to help and care for others or the impression and conviction of applicants that they will get easier at the faculty of education than any other faculty. According to Wiegerova and Gavora [4], the knowledge of motives that led teachers to choose their profession is important information. It gives evidence about situations, events, persons - family members, peers, teachers, but also career decisions. In order to understand the aspects of the professional career development of a teacher, the research must focus on period before entering into the profession. Motivation for choosing the teaching profession is one of the significant determinants for the emergence and development of teacher professionalism. Maintaining the right motivation for the entire duration of the teacher's activity is not easy at all, while being crucial to sustain the quality of work performance. The following subcategories indicate that the motives for becoming a teacher may vary. Research findings based on participants' statements show that becoming a teacher was either a substitute solution or a desire for them.

Becoming a Teacher Out of Need. Although the decision to become a teacher may seem insignificant, this decision can play a great role in the professional work of a teacher in the future, both in terms of the attitude and experience, the quality of work performance, etc. Among all the participants, some of them decided to become a teacher because they had no other choice.

> *"...actually for punishment, because I did not get a letter of recommendation for the study program at the university that I chose, so it was the only way just how to get to university, I did not want to be a teacher, definitely not, I did know it first, then I could not and I started to study the teaching ... " (UV)*

According to Kasáčova [5], the choice of a teacher's profession can be based on other than internal motives of an individual. The main reason for the situation described can be, for example, the choice of a lighter way to obtain higher education or a parental decision.

Making the Dreams to Come True. Another incentive for choice of teaching profession can be saturation of desire to work with children, the ability to stay mentally young, experiencing positive emotions in relationships with others, the need to educate, to form, to self-educate constantly. Satisfaction is based on educational studies and then a trained student passes the final exams and becomes a qualified teacher. This desire can be the meaning of life and personal fulfillment. Other partial aspirations in the profession can be identified later.

Already in early childhood, the desire to become a teacher was manifested by the fact that one of the participants played at teacher. She remembers the strong experience strongly fixed in her long-term memory.

> *"...I wanted to be a teacher since I was a little girl, I played with my brother, I was the boss, he had to play at pupil ..." (UŠ)*

3.2 Crucial Moments (The Way to Fulfill the Professional Goals)

Crucial moments are "key events in the life of an individual and his surroundings regarding turn-by-turn decisions. They guide the person to choose a particular action that leads to certain goals" [6]. These situations or events represent a significant change for teachers, a turning point in their professional career development.

The change period may have both a positive and a negative effect, and may even contain a traumatic element. Our participants have gone through several major changes. We present the results in the graphs. Each graph illustrates the development of a professional career with a crucial moment. These moments are marked with bolt font in the graph. The horizontal axis displays the time zones. The vertical axis shows the teachers' events, where the scale of values on the vertical axis is one to six. The closer the curve approaches zero, the event is perceived at a time when it is negative, the closer the curve approaches the value of six, the event is perceived positively at the time it happened.

We identified following crucial moments of our participants:

- birth of a child;
- getting the position of a director;
- termination of studies;
- loss of employment;
- aversion to changes in the education system set by the government.

The Birth of a Child. The important crucial moment that has changed the view of participant's own profession is the birth of a child. Women's emotions are changing in particular, and emotional and decision-making experiences influence the profession (Fig. 1).

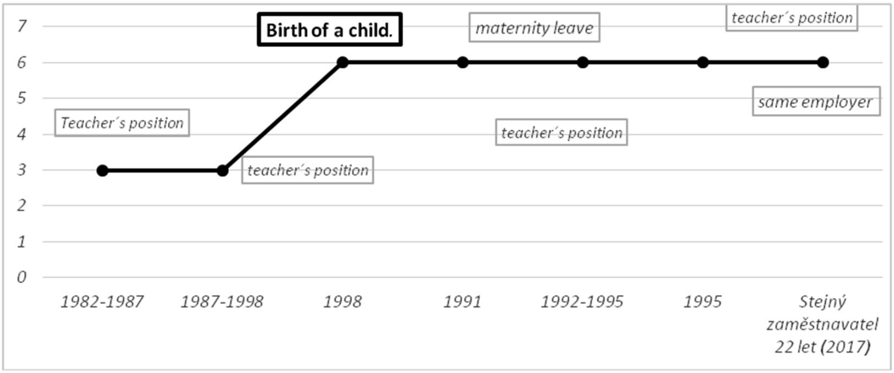

Fig. 1. Example of the development of a teacher's professional career, with an emphasis on the period of birth of the child

> *"…probably because I became a mother, I totally took it all differently, I mean in profession. I loved children but I did not take it to heart, I only took it professionally, but then when you see the kiddie grow up and you have the child always behind you, you still hold him by the hand, so you take that job completely differently…" (UI)*

Getting the Position of a Director. A person usually achieves a relatively stable and secure job at middle age. The assessment of experience and reassessment of work plans can be guided by the fact that almost a half of the professional career has already passed. The school principal is a specialist in several areas (curriculum, didactics, school management, school legislation, pedagogical innovation, etc.). Director delegates the competences optimally, creates and supports policies aimed at improving the school quality, seeks solutions to problems that have a long-term effect. Pupils and children are the top priority. In particular, organizational and leadership skills are important for the function of a director.

We can identify many reasons for becoming a director (new contacts, higher income, new experiences, personal growth, etc.), as well as the risk associated with this job, the level of social responsibility, less time for family and the possibility of changing attitudes among colleagues (Fig. 2).

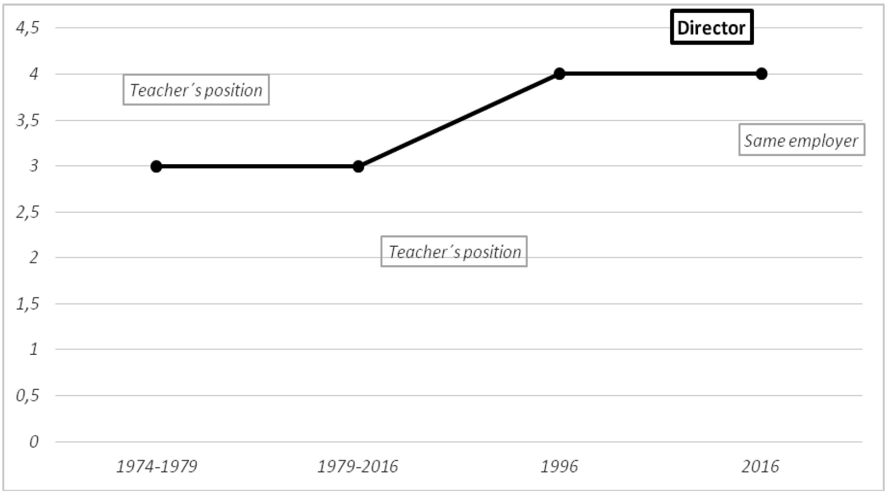

Fig. 2. Example of the development of a teacher's professional career, with an emphasis on getting a function in the profession

Termination of Studies. For some research participants, it is possible to follow two crucial moments, the first event being the professional recognition from the Czech School Inspectorate, which was the incentive to develop the skills, abilities, but above all, it supported the staying in the profession (Fig. 3).

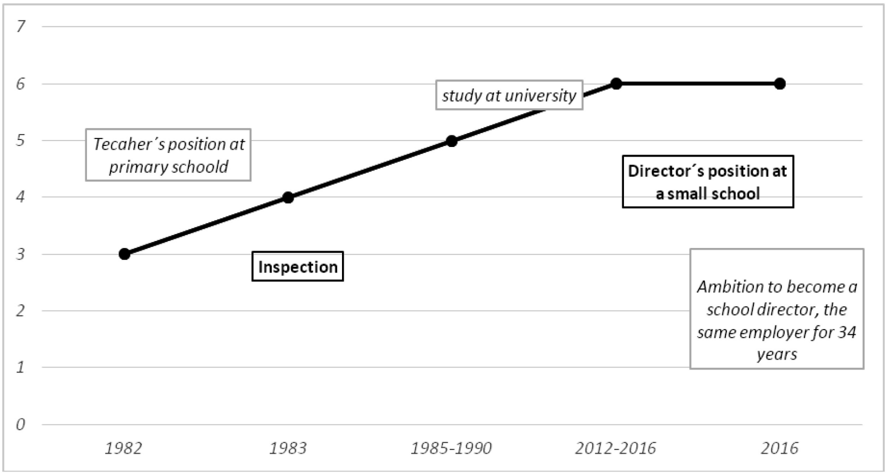

Fig. 3. Example of the development of primary school director's professional career

"…when the inspector came to school to see me, and when I was very praised, which I did not know before, I think it was actually the pulse here to continue in this profession…" (UN)

We can identify another crucial moment at the time when the participant acquired the post of director at a small primary school.

"… it was when I signed up for the competition (laugh), that I won …" (UN)

Loss of Employment. The loss of employment often contributes to the shock of reality. The participants suddenly became unemployed and did not know if they would continue in teaching (Fig. 4).

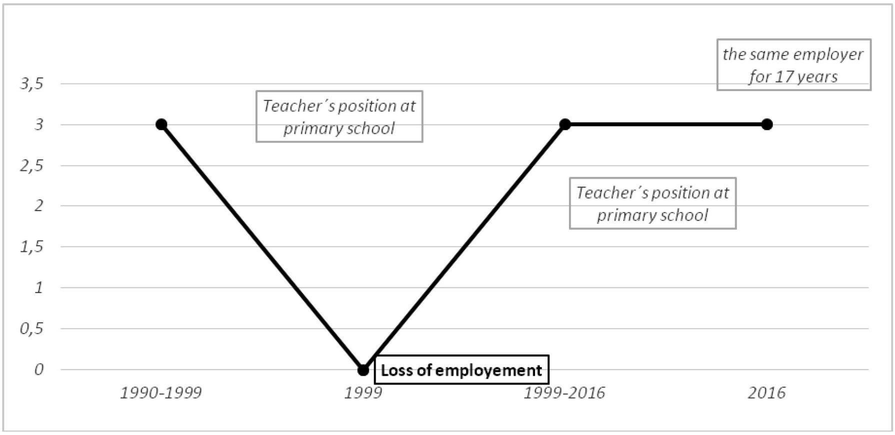

Fig. 4. Example of possible development of primary school teacher's professional career

Unexpected job dismissal is a very difficult situation for everyone. The course of this situation is based on a number of factors such as "the qualification of flexibility and rigidity, age, gender, financial reserves, the reaction of the family and the immediate surroundings, resistance to psychological stress, etc." [7] Everyone seeks employment according to personal and professional prerequisites. The most of people don't take the unexpected dismissal in a positive way. However, the loss of employment may also prove to be an impulse to change.

Aversion to Changes in the Education System Set by the Government. We can also identify the moments of leaving of some participants from education system. Teachers evaluate this step as a necessary rest. It is accompanied by disgust from the changes made by the government.

Change of life circumstances, new role of being a mother and a teacher of the child has become strong in this case and has brought another view of the teacher's profession.

"…when I became a mother, and then it was actually a chain because I changed after the birth of a sick child and then when this child was in the first grade and when I taught him some subjects because we were in the village in a really small school at the time, so I actually had two roles together, a teacher and a mother and that made me move a lot, and then it is the age with life wins and loss, so it always hits the work…" (UV)

The professional career path (Fig. 5) is typical of the frequent alternation of employer.

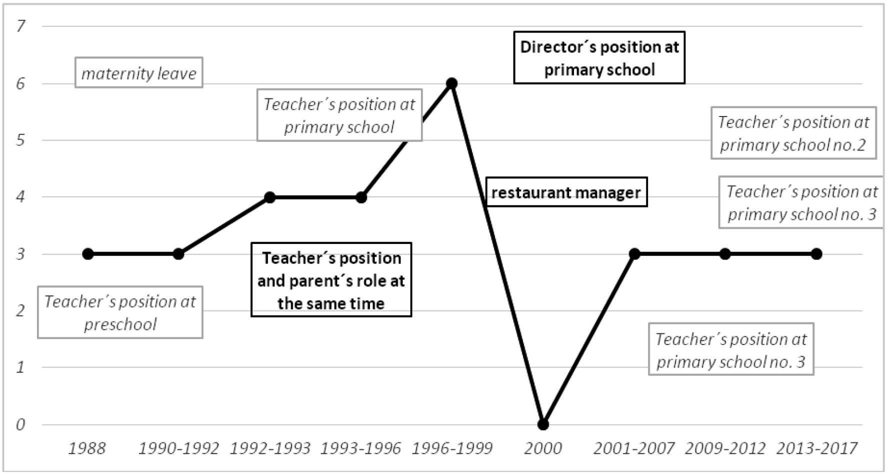

Fig. 5. Example of the professional development, with emphasis on the period outside the education system

Stagnation. During the career development of teachers, it is also possible to observe the period of stagnation, the period when the teacher gradually loses a desire for innovation and changes (Fig. 6).

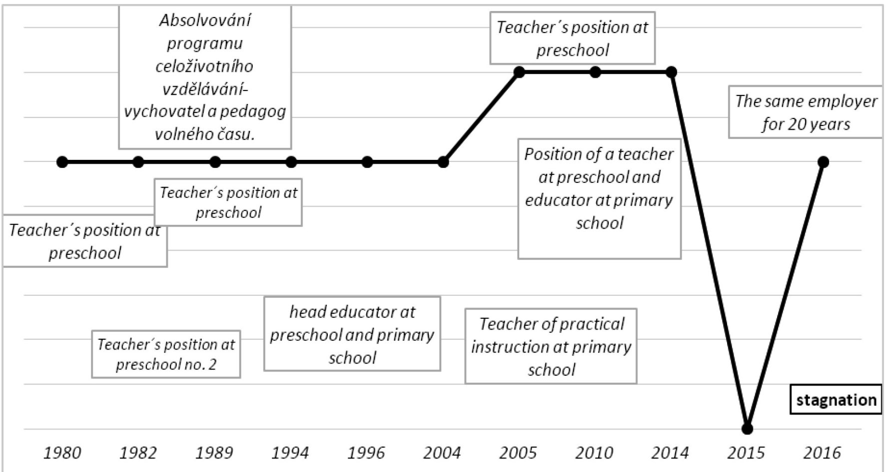

Fig. 6. Example of the preschool teacher's professional development

Also in the graph above, it is clearly visible that there are intervals of fluctuation of the teacher's work. Long-term work in the same job has both a positive and a negative influence. Staying in a stereotype can cause a drop in performance. The hostile atmosphere at the workplace or achievement of a certain position that the teacher does not want to change can be negative. According to Welsh and Welsh [8] and Deutscherová and Wiegerová [9]. one of the reasons for professional stagnation may be the fact that the possibility of career growth in a school institution has been lost because the leaders block teacher's development.

4 Conclusions

We compiled several theoretical models of the development of teachers' professional career paths, all based on the analysis of the interviews. We can regard the professional career of each teacher as unique; nevertheless, we can find some common features here.

A. *Theoretical model of teacher's professional development in case of a teacher without higher education*
This theoretical model is typical for preschool teachers without higher education. This model consists of three phases. The first phase of teacher's professional searching starts after the end of the secondary school and it continues during the next five years approximately, thus within the age of twenty-three. The next stage of teacher's professional stabilization lasts for about age of forty. Then we can talk about the next ten years as about the stage of professional conservatism when the teacher reflects the results in professional career (Fig. 7).

Fig. 7. Preschool teacher's professional path in case of a teacher without higher education

B. *Theoretical model of director's professional development in case of a director without higher education*
Another theoretical model of professional career development is typical for preschool directors without higher education. The first phase of professional searching is identical with the starting phase of the preschool teacher, as we can see at the theoretical model A. The next stage of teacher's professional stabilization continues until the age of thirty-five. Then we identified the commencement of director's ambitions, connected with a review of earlier career decisions and the teacher becomes a director. The last phase of professional conservatism occurs at the age of fifty. It is obvious that the directors do not want to change or innovate. They want to keep the leading position but also to stay calm (Fig. 8).

Fig. 8. Preschool director's professional path in case of a director without higher education

C. *Theoretical model of professional development in case of a preschool director with higher education*
This model of a preschool director's professional career development is unique, as it has only occurred for one participant in our research. The first phase of professional searching is identical with the starting phase of career development of the preschool teacher. In the penultimate phase, the teacher decides to study a bachelor degree, probably to prevent the burnout syndrome (Fig. 9).

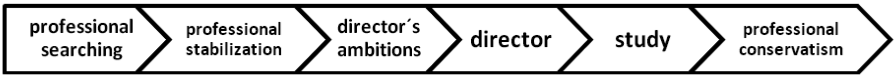

Fig. 9. Preschool director's professional path in case of a director with higher education

The last phase of teacher's professional conservatism lasts to age of sixty-five years. At this stage, there is a decline in the workforce of the teacher and the preparation for leaving the workplace and the transfer of experience to his successor at the director's position. Thus, we can say that in this case it is a prolongation of a high-quality professional career.

D. *Theoretical model of professional development in case of primary teacher*
This theoretical model of professional career development is characteristic for primary school teachers. The law in the Czech Republic requires a higher education for primary teachers (comparing to preschool teachers with only secondary education being sufficient). Thus, the first phase of teacher's professional searching starts at the age of twenty-four and continues until the age of twenty-nine years approximately. The phase of teacher's professional conservatism of a primary school teacher lasts typically from the age of forty-five until the age of fifty-five years (Fig. 10).

Fig. 10. Primary school teacher's professional development

E. *Theoretical model of primary school director's professional development*
The first phase of teacher's professional searching is identical to the development presented in model D. The phase of professional stabilization lasts from the age of

twenty-four years after teacher's post-graduate studies and it continues until the age of thirty-five approximately. Then the teacher begins to follow the leadership ambitions, caused by appreciation of professional decisions. The last phase of professional conservatism lasts from the age of fifty until the age of sixty-five years approximately (Fig. 11).

Fig. 11. Primary school director's professional development

All presented models of professional career development of preschool and primary teachers coincide in the developmental stages of the career path. The models are differentiated by the age of commencement in employment, which correlates with the termination of studies; a primary school teacher begins to work at the age of twenty-four years, a preschool teacher from the age of eighteen years. Therefore, (preschool teachers enter the profession five years earlier than primary school teachers do), preschool teachers are experiencing early professional extinction.

By comparing the teacher's career development models, the results of our research study shows that a preschool teacher as well as a primary school teacher did not go through all the stages of career development described above. They may skip some phases, go back to the previous stage or completely omit the phase. In addition, the timing of individual phases of career development may not be precisely defined. Therefore, our study provides opportunities for further comparisons and answers to questions as to how teachers' career paths are developing and what is fundamental for their professionalization.

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Redesign of Chinese Traditional Culture: Take Longmen Grottoes as an Example

Tian Lei, Sijia Zhang(✉), Nan Ni, and Ken Chen

School of Mechanical Science and Engineering,
Huazhong University of Science and Technology, Wuhan, China
andrew.tianlei@hust.edu.cn, 417057184@qq.com

Abstract. This article starts with the issue of "how to make the history and culture of the Longmen Grottoes widely spread in the youth group". First of all, it selects the content that is suitable to pass to the youth through the collation of relevant historical data of longmen grottoes. Second, by analyzing the competitive products, this article integrates the styles of cultural App-design, and selects the most suitable form of cartoon style for young people, combining with the actual style of grotto art to carry out visual design. If the Longmen grottoes, a "large historical and cultural database" can be displayed in the form of App, which will not only enable the youth to learn and understand the grotto art and the chinese historical culture extending from it, but also can play a better propaganda role to the Longmen Grottoes, thus stimulating the development of related industries such as tourism.

Keywords: Longmen Grottoes · Grotto art · App-design · Youth group
Cultural diffusion

1 Introduction

With the rapid development of Chinese economy, the spiritual and cultural needs of Chinese people are gradually enlarged. In recent years, the development and inheritance of classical history and culture has attracted people's attention. However, under the impact of the current rapid pace of life, some classical historical cultures are facing the situation of gradual loss due to regional restrictions and lack of dissemination [1]. The popularity of mobile devices and the explosive increase of mobile applications APP provide a new communication platform for classical history and culture. I Media Research data shows that in 2015, the traditional historical and cultural information browsing has become the main demand point of the user, accounting for 61.2%. Traditional historical and cultural tools and educational learning rank respectively No. 2 and No. 3, accounting for 44.6% and 31.7%, respectively (Fig. 1 shows an example).

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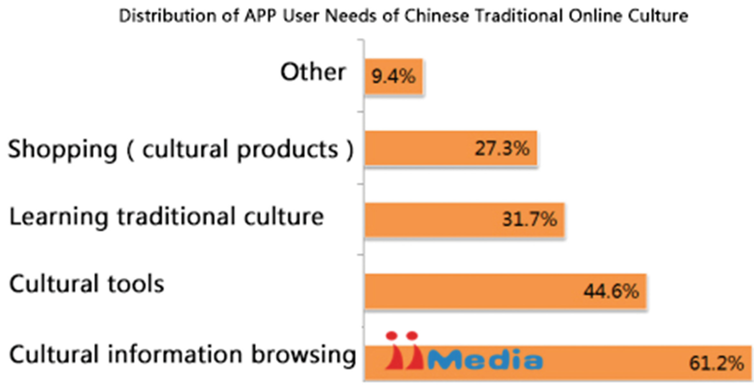

Fig. 1. Distribution of APP user needs of Chinese traditional online culture

Nowadays, teenagers, represented by student groups, have gradually become the largest user group in the use of cultural App in recent years, as shown in Fig. 2. However, for young people, the art of Chinese grottoes, represented by Longmen Grottoes, brings them more impression of visual surface level than the strong historical culture behind it. It has become a topic worth studying on how to convey the history and culture of Longmen Grottoes to children more vividly.

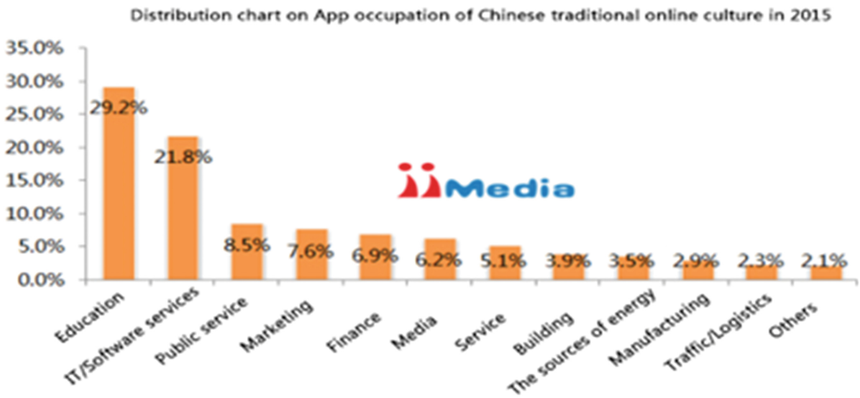

Fig. 2. Distribution chart on App occupation of Chinese traditional online culture

Longmen Grottoes also have great market potential as a famous scenic spot. In 2015, from the growth rate of the national tourist attractions in the 11th Golden week survey by Tencent. The number of people in Longmen Grottoes has increased by more than 50,000 people per day, ranking first among many scenic spots in the country, and its popularity is also in the forefront of tourist attractions in the country. However, the expanding tourism market has not been born with high-quality applications. The corresponding cultural App appears to be imminent.

2 Literature Review

Longmen Grottoes can be built in history to the Northern Wei Dynasty. When Emperor Xiaowen moved his capital to Luoyang, he brought Buddhism culture. After the Eastern Wei, Western Wei, Northern Qi, Sui, Tang, five dynasties, Song and other dynasties, especially in the Tang Dynasty, the cave construction reached its peak. More than 400 years of construction, large or small, has resulted in a total of 1,000 meters of north and south, 2,345 caves containing more than 100,000 statues, and more than 2,800 inscriptions on inscriptions in the caves [2]. It can be seen that the historical culture of Longmen Grottoes is very rich and valuable. And also as the Dunhuang Mogao Grottoes, Yungang Grottoes are known as the three great Chinese grottoes art treasure. It is solid stone, carefully carved, a variety of shapes, large inscriptions and civilized in the world. Because of magnificent style, extensive area, the exquisite grottoes internal Buddhist sculpture, and rich content, it was also listed as one of the world's greatest classical art treasures.

In China, there are three main ways for teenagers to learn about history and culture: school education, life experience and effective involvement in cultural resorts and existing museums. Some of the knowledge and information taught in school is limited and uninteresting, while the knowledge and information gained from the life experience shows little or no consistency. It also shakes the important position of history and culture in the mind of young people. Therefore, it has long been popular for cultural resorts and existing museums to become an important role in cultural communication and the expression of different cultural values of conflict and dialogue window [3] (Fig. 3).

Fig. 3. Longmen Grottoes scenic area

Just as Nicholas Negroponte, a famous American scholar, put forward the concept of "digital existence" in the middle of 1990s, In 21th century, with the advent of the information age, people's living environment is becoming more and more digital. Information is disseminated through various media. With the increasing consumption rate of modern parents' digital electronic products, iPhone and iPad have become children's favorite toys [4]. A survey shows that in the current APP market, the APP of young children is on the rise. "History popular Science Education" has become a very popular design theme. It can make the user interact with the media carrying history and culture in the way of touch screen, so that the boring historical record can be displayed in rich and colorful ways, and the history and culture will become more interesting and easy to learn. If the Longmen Grottoes, a "large historical and cultural database," can be displayed in the form of APP, children not only can understand the historical and cultural mysteries of the Grottoes easily, Better learning and understanding of grottoes art and its extension of Luoyang regional history and culture can also play a better role in promoting Longmen Grottoes thus stimulating the development of tourism and other related industries. 140 questionnaires are collected to find out the cognition of Longmen Grottoes in Chinese people. It can be seen that this APP has considerable room for development.

3 Similar Product Analysis

Teenagers' ability to know things is relatively weak and their attention is not focused enough so that they are unable to concentrate for a long time in order to accomplish some purpose as adults do. This also requires interface designers to keep this in mind when designing APP, and try to simplify the interface of APP so that they don't feel disgusted when they work with complex interfaces for a long time. By browsing and classifying the relevant App on the App Store of IOS system, it is found that the current youth culture APP not only has the functions of introducing history and culture, enterprise culture and regional culture, but also combines with other functions, such as taking notes, logs, even camera functions, etc. The diversification of APP functions is also the current design trend, and its style also changes with the content of App. In order to find the common features of cultural App design style, 5 kinds of popular Chinese traditional culture APP on the market have been selected to carry on the page layout, the color, the pattern, the element induction and the summary in order to find out the common ground conveniently, as shown in Table 1.

Table 1. Comparative chart of cultural App design style

Name	Every day in the Imperial Palace	Mortise & Tenon	Emperor's daily life	Museo Ceramica	Ci
Main body	Pictures and words	3D animation)	Animation	Pictures	Words
Maincolors	White	White	Yellow	Dull grey	Dark blue
Cultural elements	Cloud grain	The tenon and mortise joint	Cloud grain,Scroll	Chinese porcelain	SongCi Poetry
Instance					

4 APP Interactive Prototype Design

Through the inspection of Longmen Grottoes and the analysis of their historical review, the product is initially positioned as a cultural promotion APP featured by e-book nature and is divided into two core components.

Core content (1) Map browsing line. It has the function of introducing the scenic spots of Longmen Grottoes, that is, acting as a guide, so that users can understand the art of the grottoes in front of them more vividly during the browsing process. It can also let those who are interested in Longmen Grottoes but do not have the opportunity to visit them stay indoors and directly participate in the sightseeing of Longmen Grottoes across time, place and environmental factors.

Core content (2) Museum browsing line. It has the explanation function for the historical documents behind the Longmen Grottoes, the surrounding folklore culture, folk story. This function enables users to explore and understand the historical and cultural aspects of Longmen Grottoes, such as carving history, carving techniques, Buddha stories, folklore and so on, while watching Longmen Grottoes scenic spots, so

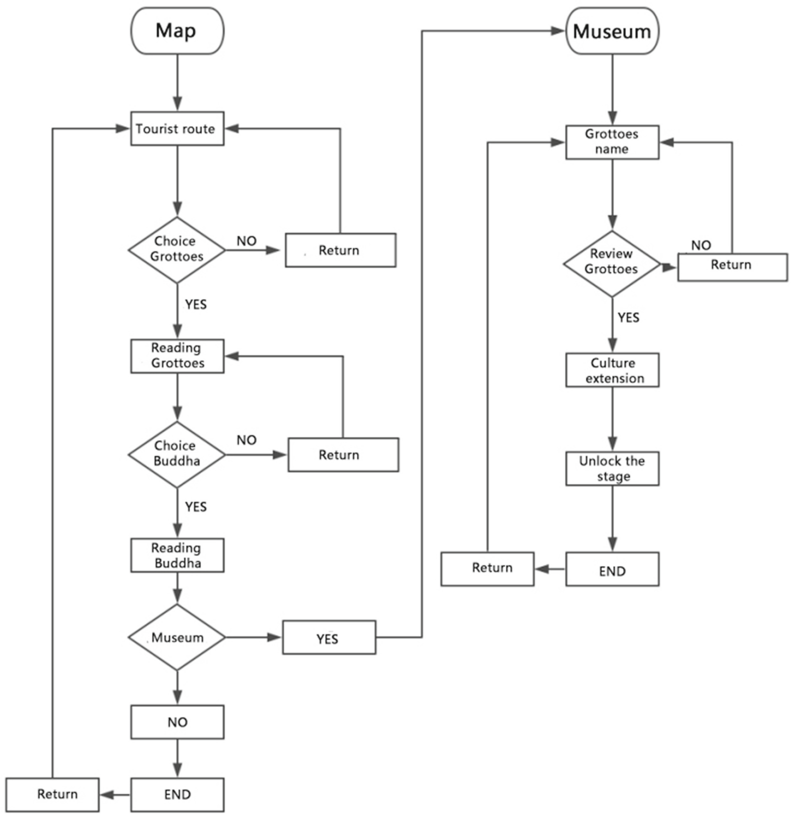

Fig. 4. One Two core elements in app design

as to learn the cultural essence of Longmen Grottoes in a more comprehensive way thus avoiding only paying attention to the surface of the scenic spot and ignoring the connotation of the scenic spot browsing state (Fig. 4).

The interface is mainly divided into five big parts: entrance interface, map interface, scenic spot interface, introduction interface, museum interface, and museum browsing interface (Fig. 5).

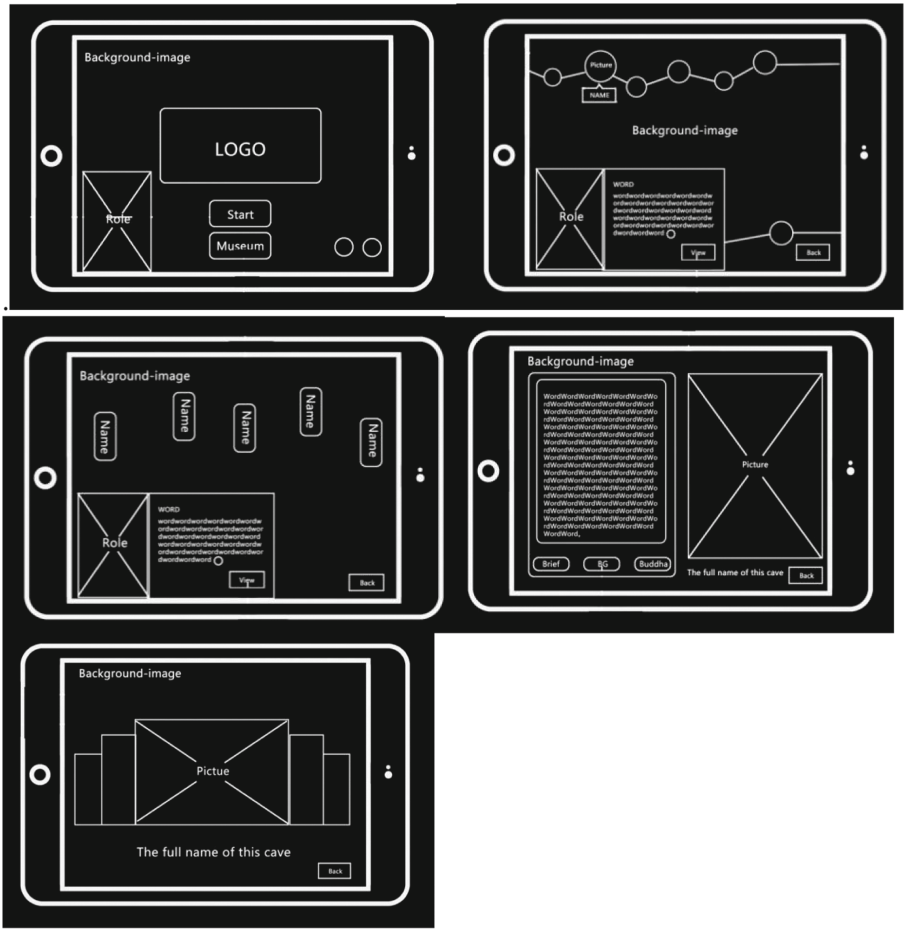

Fig. 5. Entrance interface, map interface, scenic spot interface, introduction interface, museum interface, and museum browsing interface.

5 Visual Design of APP Interface

For the interface style selection, the cartoon style is chosen as the interface style of the whole App. Cartoon style can also be called animation style, which is very popular among teenagers and children. It is different from the realistic style, to a great extent, exaggerating the characters/things to be displayed, the whole picture is humorous, vivid and interesting. In the color, this style takes the high purity bright color primarily. Even monotonous scenes look lively and interesting.

5.1 Entrance Interface

Taking the entrance gate of the actual scene of Longmen Grottoes as the background, the Katonification design is carried out. The role of tour guide takes the pottery figurines of the Tang Dynasty as the archetype for the design of Katonization. She mainly acts as a guide in the game, leading users to play the Dragon Gate, four buttons are divided into two big "start(Map)" and "Museum" buttons respectively and the secondary page could be entered through click, while the other two small buttons are "Settings" and "about." The "Settings" button could adjust background music, voice volume, and so on, while the "about" button allows you to view developers, designers, and so on (Fig. 6).

Fig. 6. Entrance interface

5.2 Map Interface

The map interface originates from the redesign of the original map of Longmen Grottoes, and it is deleted and adjusted according to the need of style. When the original scenic spots remain unchanged, the caves are reduced and distributed on the map in proportion to the original ones. Because the original landform of Longmen Grottoes divides the view route of the scenic spots into two parts, the map interface is also made up of two areas. In order to make APP more interesting and attractive, the site is set up as an unlocked one, that is, the browsing of the previous one shall be completed before getting to the next one (Fig. 7).

Fig. 7. Map interface

5.3 Scenic Spot Interface

The scenic spot interface is the third level interface in the map interface that enters by clicking on the scenic spot. The background of the scenic spot is the Buddha or building in the original scenic spot. Each Buddha or building is marked with a name, which serves as a button to the next level of the interface. When the user clicks together with the first level map interface, the guide bar appears, also has the voice function, the user can move to the left and right interface to view the entire view of the scenic spot (Fig. 8).

Fig. 8. Scenic spot interface

5.4 Introduction Interface

Take the Lucerna Buddha in the scenic spot of Fengxian Temple as an example. The background color imitates the color of Kraft paper, creating a style that seems to be turning over the historical scroll. On the left side there is a text bar that can be viewed up and down, and on the right it is a physical picture, because it is crucial to introduce the real historical and cultural heritage. So inserting a physical image is necessary. This four-level interface is one of the most common interfaces in the whole APP. It introduces the construction background, allusions and so on of the Buddha statue or architecture selected in the three-level interface. Users can use the button in the lower left corner to enter the corresponding explanation page and browse the introductory text by sliding up and down. At the same time they can also look at the right side of the relevant pictures, graphic and text combined with a deeper understanding (Fig. 9).

Fig. 9. Introduction interface

5.5 Museum Interface

The interface, like the map interface, belongs to the secondary interface. It contains three categories of “Northern Wei grottoes”, “Tang grottoes” and “other” categories of Longmen Grottoes, which are classified according to the years of construction. The user can open the entrance of the next interface by sliding the same button of the three scrolls on the left and right. The museum interface is associated with the unlocking system of the map interface, that is, the corresponding cave must be unlocked at the map interface, and the corresponding level here will be unlocked (Fig. 10).

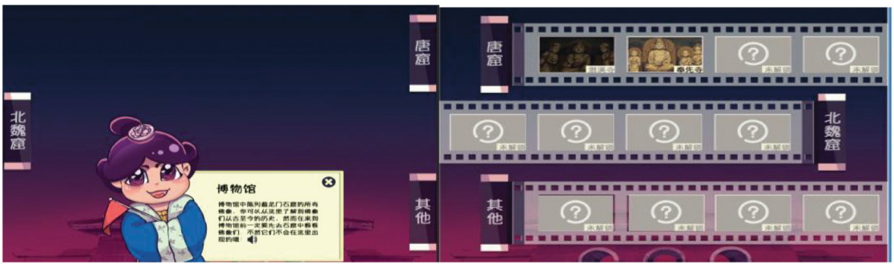

Fig. 10. Museum interface

5.6 Museum Browsing Interface

The interface is a three-level interface, similar to the introduction interface, and also one of the most common interfaces in the whole APP. The user came in by clicking the grotto button in the previous interface. The interface introduces the history and culture around the cave such as the year of the event, Buddha costumes, carving methods and so on, and users can use this interface pictures left and right to see the relevant pictures and text, as if browsing the general experience of books. The pictures are arranged according to the time order, when the left and right slide, the picture can be observed to zoom in action, making the interface more visual impact (Fig. 11).

Fig. 11. Museum browsing interface

6 Summary

Nowadays App has become another emerging platform for the promotion of history and culture. Longmen Grottoes, as a treasure in the Chinese cultural library, has not been launched by the excellent App and the introduction of tourists is not enough for the full understanding on the classical history and culture of the grottoes art. On the one hand, our APP promotes the history and culture of Longmen Grottoes so that more people can understand its charm. On the other hand, it also promotes the attraction of Longmen Grottoes to teenagers and provides a reference for the promotion of grotto art and culture.

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Scientific Concepts in Educational Science

Spatial Ability for University Biology Education

Juan C. Castro-Alonso[1(✉)] and David H. Uttal[2]

[1] Center for Advanced Research in Education (CIAE), Universidad de Chile, Santiago, Chile
jccastro@ciae.uchile.cl

[2] School of Education and Social Policy, Northwestern University, Evanston, IL, USA
duttal@northwestern.edu

Abstract. Studying and pursuing careers of Science, Technology, Engineering, and Mathematics (STEM) fields demand spatial ability. Completing a university degree in biology is no exception. The aim of this study is to summarize key findings showing that there is a two-way relation between university biology education and spatial ability. The first aspect of this relation is the most investigated: spatial ability facilitates learning biology. However, the other aspect is also possible: learning biology may improve spatial ability. We present empirical evidence to support both possibilities. The focus is on university biology, and the spatial abilities of mental rotation and mental folding (spatial visualization). We present findings showing that these spatial abilities affect university biology learning and achievement from textual and visual materials. We also present correlational studies and experiments showing that university biology learning positively affects mental rotation and mental folding.

Keywords: Biology · STEM · Spatial ability · Mental rotation
Mental folding and spatial visualization

1 Introduction

We know that learning and practicing Science, Technology, Engineering, and Mathematics (STEM) requires high levels of spatial ability [1]. The relation between STEM achievement and spatial ability seems to be stronger in Engineering, Physical Science, and Maths/Computer Science, as compared to Biological Sciences [2]. For example, Hegarty [3] used an on-line instrument to assess the self-rated spatial abilities of over 700 professionals. Notably, biologists rated their spatial abilities as rather low; their self-ratings were comparable to those of the humanities professionals, and markedly lower than the self-ratings of respondents from physics, geosciences, or engineering. Nevertheless, this difference does not mean that studying and pursuing a biology career does not request spatial abilities, as the ratings in this study were based solely on self-assessment. In fact, thriving in university biology demands spatial abilities such as mental rotation and mental folding. Consider three examples: (a) mental rotation is necessary with tasks involving macroscopic and microscopic biology [4]; (b) mental rotation helps in rotating biochemistry and chemistry molecules, and mental folding assists learning about protein structure and folding [5]; and (c) mental rotation aids in the use and understanding of difficult 3D models of animal and plant cells [6].

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However, these spatial abilities not only help in learning university biology, but the other direction of effects may also be observed (see Sect. 4). As such, the aim of this review is to summarize key findings showing the two-way relation between success in learning university biology and spatial ability. Here, we focus on university participants, and the spatial abilities of mental rotation and mental folding, which are described next.

2 Spatial Ability as Mental Rotation and Mental Folding

Mental rotation is the ability to perceive a whole figure and rotate it with the mind [e.g., 7]. There are three-dimensional (3D) and two-dimensional (2D) tests of mental rotation, the former requiring three and the latter demanding only two axes of rotation. Tests to measure mental rotation, both of 3D and 2D objects, typically involve comparing a target shape against "same" (rotated) or "different" (mirrored and rotated) figures. A distinctive feature of mental rotation, reported by Shepard, Metzler [8], is that the greater the difference in angles between the target and the test images to rotate and compare, the longer it takes. In other words, mental rotation may be the mental equivalent of a manipulative rotation.

Mental folding (also known as spatial visualization) employs mental rotation but also additional resources involving mental restructuring and serial operations [e.g., 7]. As reported in Shepard and Feng [9], tasks involving more steps of mental folding will demand more time than tasks that involve fewer folds. Hence, as in mental rotation, mental folding may be the mental equivalent of a manipulative folding.

Because mental folding relies partially on mental rotation, mental folding test scores are usually correlated with mental rotation test scores [10]. For example, in a study with 170 adults [11], there were medium to large correlations (all rs > .45, all ps < .01) between instruments of 3D mental rotation, 2D mental rotation, and mental folding. Similarly, Vandenberg and Kuse [12] investigated a large sample of participants, ranging in ages from 14 to 60 years, and reported medium to large correlations (all rs > .39) between tests of 3D mental rotation, 2D mental rotation, and mental folding. Because of the generally high correlations between mental rotation and mental folding, the two abilities are often included in the same category of spatial abilities. For example, a recent meta-analysis [13] incorporated both in the group of *intrinsic* and *dynamic* spatial abilities. Both mental rotation and mental folding are intrinsic because they involve transforming mentally the properties of an object, so is an intrinsic manipulation to that object. Both abilities are dynamic because the object must be imagined in motion, such as with rotations or folds.

Despite the similarities, mental rotation and mental folding do differ [10]. An important difference [14] is that mental rotation is a rigid body mental transformation (the distances between the points of the objects are preserved), whereas mental folding is a non-rigid body mental transformation (the distances between the points of the objects can be changed). Another important difference is that men generally perform substantially better than women on mental rotation, but the sex difference is smaller for mental folding tasks [see 15].

Standard instruments that measure 3D mental rotation are: (a) the Mental Rotations Test, (b) the Cube Comparisons Test, and (c) the Purdue Visualization of Rotations. The

Mental Rotations Test was developed by Vandenberg and Kuse [12], employing shapes like those used by Shepard and Metzler [8]. Every item of this instrument presents an abstract 3D shape, like a "Tetris" blocks, and four comparable images at the side. The task is to mark which of the response options are a rotated version of the target. The other two shapes, which are both rotated and mirrored versions of the target, should not be marked, as they are incorrect (see Fig. 1a). The second standard 3D instrument, the Cube Comparisons Test, was included in the battery of Ekstrom et al. [7]. The respondent is asked to compare two cubes with different letters in their faces. The participant must determine if the two cubes are rotated version of each other or entirely different. Lastly, the Purdue Visualization of Rotations was reported by Pribyl and Bodner [16]. Participants are given two identical 3D shapes, one rotated in relation to the other, and they must solve how the volumetric shape was rotated, so they can apply the same rotation to a new shape.

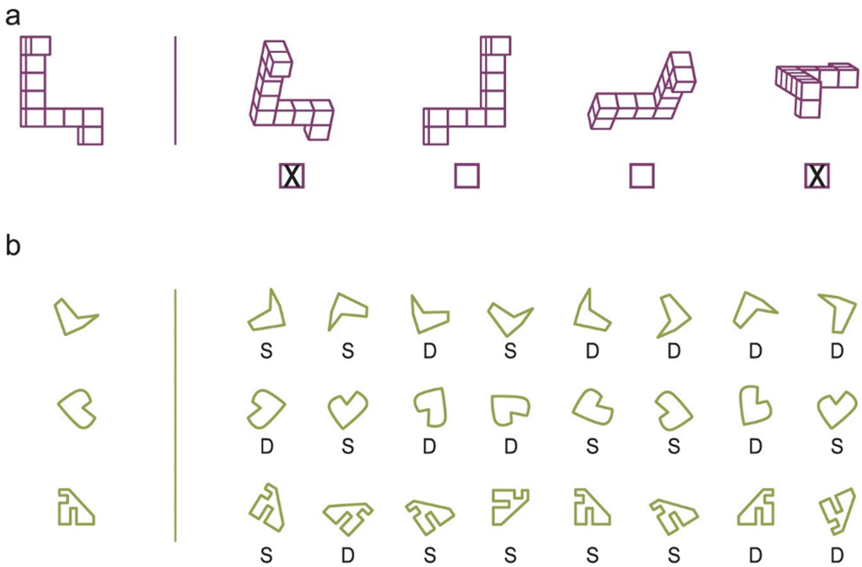

Fig. 1. (a) Adapted item from the Mental Rotations Test. (b) Three items from the Novel Virtual Card Rotations Test. The correct answers in both tests are shown.

Regarding 2D mental rotations, a standard instrument to measure this spatial ability is the Card Rotations Test, which was developed by Ekstrom et al. [7]. Every question of this instrument asks the participant to compare one abstract shape to eight different versions at the side. The task is to judge which of these depictions are the same shape, only rotated, and which are both rotated and mirrored. There is a recent version of this test, the Novel Virtual Card Rotations Test [17], which is computerized and includes new abstract shapes. By clicking the computer mouse, the answer is toggled between S (same) or D (different; see Fig. 1b). In addition, there are several instruments that have been developed to measure 2D mental rotation with original illustrations, including abstract shapes [e.g., 18], molecular diagrams [e.g., 19], and symbolic figures [e.g., 20].

A number of standard tests are used to measure mental folding or spatial visualization. These include the Paper Folding Test and the Surface Development Test, which are both included in the battery by Ekstrom et al. [7]. In the Paper Folding Test, several folds are made to a sheet of paper, and then the folded paper is punctured. The participant's task is to determine how the holes would look when the paper is unfolded, comparing among five alternatives (see Fig. 2). In the Surface Development Test subjects are asked how a 2D flat depiction would fold into a given 3D volumetric shape. Results of these mental folding tests, as those of mental rotation instruments, have been linked to results in university biology education, as described next.

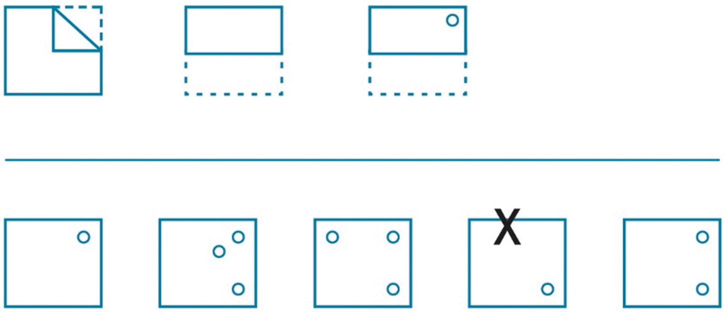

Fig. 2. Adapted item from the Paper Folding Test. The correct answer is shown.

3 Spatial Ability Affects Biology Learning and Achievement

Biology education involves textual (verbal) materials, as well as visualizations. In both cases, spatial ability is an important asset. An example regarding textual information is Fiorella and Mayer [21] study of undergraduate participants learning from text-only passages about the human respiratory system. A composite score of spatial ability was calculated from tests of 3D mental rotation and of mental folding. Results showed that spatial ability was a significant predictor for learning, including measures of retention, transfer, and also drawing. In a related area to biology, that of meteorology [22], two experiments with a total of 144 university students (64% females) assessed learning about the phenomenon known as El Niño. The participants were given textual-only passages of this weather topic, with or without the aid of written analogies. Mental folding scores predicted performance in this weather phenomenon for all learning measures.

In addition to these examples of spatial ability aiding textual understanding, most of the studies involve understanding materials that also include visualizations. For example, the study by Bartholomé and Bromme [23] with 84 university participants (77% females), used an aggregated score of spatial ability. This score, which combined mental rotation and other spatial skills, was significantly corelated with learning multimedia botany. Likewise, Huk [6], investigated 106 high school and university biology students (67% females) learning multimedia cell biology. High 3D mental rotation ability students could learn better with the inclusion of 3D models of the cells, as compared to low mental rotators. A follow-up study [24] was conducted with 112 high school and university biology participants (64% females) learning the same topic. Only high 3D mental rotators befitted from connecting lines designed to help understanding the cellular structures. Another example is provided by Loftus et al. [25]. Investigating 29 adult participants (35% females), the authors produced a split between high and low 3D mental rotators. In this case, those exhibiting high spatial ability could solve human anatomy problems (involving cross-sections, mental rotations, and intersecting planes) better than those with low spatial ability. In the Experiment 2 of the study reported by Mayer and Sims [26], the 2D mental rotation and mental folding of 97 university participants was measured. The students were given a multimedia module of the human respiratory system, in which a short animation and concurrent narration explained the inhaling, exchanging, and exhaling processes. After watching these animations with simultaneous narrations, students were given transfer problems. Participants in the high spatial range outperformed those in the lower side. Experiment 2 in [27] involved 78 university participants (74% females) studying a multimedia presentation about the structure and function of the enzyme ATP-Synthase. Spatial ability, measured with 2D mental rotation and mental folding tests, was a significant predictor of performance in the comprehension and transfer tests. Another example with visualizations comes from Brucker et al. [28], who studied 80 university participants (75% females) learning fish swimming patterns under different presentation conditions. Regression analyses showed that 3D mental rotation was a significant predictor of learning from these visualizations. In the related realm of health sciences [29], 146 anatomy students (50% females) learned from computer visualizations of a human hand model. Scores in a previous 3D mental rotation test were significant predictors of higher grades in the hand anatomy test. Also, in a related area of memorizing symbolic elements [30], it was observed that for 104 university students (50% females), 2D mental rotation could predict their accuracy in these abstract tasks, after studying them from either animated or static presentations. For a last example [4], the 3D mental rotation and mental folding of 250 university students was assessed with standard tests at the beginning of a biology course. Those in the lowest third of spatial ability were divided into experimental and control groups, and the treatment involved spatial activities with volumes and shapes. At the end of the course, students who received spatial training outperformed the control group in the final biology assessments, which involved, among other tasks, the interpretation of graphs and diagrams, and the understanding of macroscopic and microscopic biology.

In short, the evidence, employing educational materials with textual information and visualizations, suggests that spatial ability, as measured through mental rotation or mental folding, supports biology learning. The opposite direction, that of biology knowledge and practice supporting spatial abilities, is described next.

4 Biology Learning Affects Spatial Ability

The potential influences of learning biology on performance on spatial ability tasks has been less investigated than the opposite direction, but evidence is mounting that learning biology does affect mental rotation and mental folding. The literature that shows these effects can be categorized in (a) correlational studies or (b) experiments. Correlational studies show that spatial ability is correlated with biology or science participation. In other words, students from biology or related science disciplines tend to outperform students from different areas in spatial ability tests. For example, Sharobeam [31] investigated university students ($N > 700$) from different majors, mostly from Years 3 and 4. They were measured in a novel test of mental rotations in 2D and 3D. The researchers compared the performance of participants in the science fields (biology, biochemistry, computer science, geology, marine science, physics, others) versus those in non-science fields (business, economics, education, language, literature, philosophy, sociology, others). Science participants (66% correct answers) significantly outperformed non-science students (52% correct). Recruiting a larger number of university students ($N > 2000$), Peters et al. [32] reported analyses of three studies, combining Canadian, German and Japanese samples. When measuring performance on the 3D instrument Mental Rotations Test, participants in the sciences disciplines significantly outperformed students in the social sciences programs, with medium to large effect sizes. These outcomes were observed in each of the three countries.

In general, experimental evidence allows more robust conclusions than correlational evidence. An example of experimental findings is the work of Macnab and Johnstone [33], who investigated the spatial abilities of participants ranging from primary school to the postgraduate level. In addition to reporting an improvement of mental rotation and mental folding with age, the researchers found that these spatial abilities were higher in the participants who had taken biology classes, as compared to students without this academic background. Another example is Lennon [34], who studied the effects of weekly modeling with clay bacteria on three spatial abilities in 59 microbiology undergraduates. Although the effects on mental rotation and mental folding were non-significant, the modeling treatment was effective for the related spatial ability of field independence. In the discipline of human anatomy, which is related to biology, Lufler et al. [35] investigated 255 first-year medicine students who belonged to a gross anatomy course. The semester course included three main sections: head and neck; back and limbs; and thorax, abdomen, and pelvis. Students were required to dissect cadavers and study 2D anatomical images from textbooks and radiographs. For both genders, 3D mental rotation improved from the beginning to the end of the anatomy course. From another related area, that of veterinary science, Provo et al. [36] investigated 128 students (75% females) enrolled in a canine anatomy class. The researchers found that the class was effective in improving the scores in a test of 3D mental rotation.

5 Conclusion

Pursuing university biology education and following a biology career later demand spatial abilities, such as 2D mental rotation, 3D mental rotation, and mental folding. This review showed that the relationship between spatial ability and biology is two-ways: spatial ability can help biology learning and achievement, but also biological knowledge and practice can improve spatial ability. Future research may reveal new variables involved in this two-ways relation.

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Expanding Student Teachers' Implicit Theories About Explanations for the Science Classrooms

Valeria M. Cabello[1(✉)], Maria Antonietta Impedovo[2], and Keith J. Topping[3]

[1] Departamento de Estudios Pedagógicos, Centro de Investigación Avanzada en Educación, Universidad de Chile, Santiago, Chile
valeria.cabello@uchile.cl
[2] Aix-Marseille Université, ADEF EA4671, 13248 Marseille, France
maria-antonietta.impedovo@univ-amu.fr
[3] University of Dundee, Dundee, Scotland
k.j.topping@dundee.ac.uk

Abstract. This study explored student teachers' implicit theories about explaining for the science classroom in three courses at diverse universities. Based on microteaching situations, the participants simulated explanations and discussed the elements they considered relevant for giving peer feedback. This led to the design of rubrics for peer assessment, which expressed their implicit theories about what a good explanation for the science classroom would look like. The three rubrics are presented and discussed in the light of the connections between teachers' thinking and practice. Shulman's ideas about professional teaching knowledge development, as well as negotiation of meaning, provide theoretical under-pinning for understanding and expanding student teachers' thinking about explanations for the science classrooms.

Keywords: Explanations · Implicit theories · Science education
Peer feedback

1 Introduction

1.1 Implicit Theories in Teachers

Implicit theories are a system of thoughts with a certain degree of articulation, not totally codified by their owners -because of their implicit character- but typically inferred and reconstructed by researchers [1, 2]. These theories also could be idiosyncratic to a group or community. They have an important function in intergroup relations, mediating the construction of social meaning - and they have a regulatory effect on action [1, 3]. The origin of the examination of implicit theories was in cognitive psychology, as the product of implicit or informal learning and the construction of regularities in the world, in order to make it more predictable and controllable [4]. Moreover, they are representations that make connections between information units, which adds complexity [4]. Although implicit theories could be

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considered as a type of belief [1], in fact they are deeper, more stable and more difficult to change [3]. This might be because implicit theories tend to be eclectic aggregations of propositions from many sources, rules of thumb, and generalizations drawn from personal experience, values, biases and prejudices [2]. In the theory of Nonaka and Takeuchi [5], this would constitute tacit knowledge, which is conceived as the fruit of a multiplicity of non-verbalized internal sources (personal beliefs, perspectives and values). Explicit knowledge, on the contrary, is easily-accessible, expressed and shared formally. For instance, in this research we worked with explanations of scientific concepts as a form of explicit knowledge. We conceptualized explanations and explanatory frameworks as the way in which teachers use analogy, metaphor, examples, axioms and concepts, linking them together into a coherent whole for the classroom [6].

Teachers are not used to articulating their knowledge of practice, and as a consequence, they usually know more than they can say about what they do. This tacit knowledge includes reasons for approaching teaching practices in particular ways, knowledge of teaching procedures and their impact on students' learning [7]. We will focus specifically on the organization and modification of implicit theories.

1.2 Modification of Implicit Theories

To understand how teacher theories can change, it is necessary to understand how they are organized. As is shown by Pozo et al. [8], at the surface level of representational analysis there are the beliefs, conceptions, predictions, judgements and interpretations that people enact to face situations or tasks. This level is more accessible and explicit for the person because it is in a more conscious level of representation. Changing theories requires a deep restructuring of implicit suppositions, conducting a conceptual change to overcome the restrictions imposed by the person's cognitive system. This change should operate on the deepest conceptual structures to construct new knowledge [4]. According to Karmiloff-Smith [9], a specific level of representation should be re-described in new and more complex categories in a sequence of progressive complexity, in order to integrate or re-interpret previous ideas into others that are more structured.

As implicit theories are a cost-effective way of reasoning, to be restructured they need to be confronted with practice [4], to make them explicit and re-integrated [8]. This means making theories progressively fit into a position where they can be affected [10]. Concept maps, metaphors and flow charts are techniques to aid teachers in the elucidation of thoughts and theories. Moreover, using the same information input twice offers the possibility to look for transformation [11]. As a goal of teacher education is to help student teachers to challenge and refine their ideas about teaching, cognitively supportive environments are needed [12]. Effective teacher education programmes recognise the development of teachers' knowledge about teaching practices for specific objectives [13]. In the current research, implicit theories held by student teachers about explaining for the classroom were investigated, through the optic of constructing criteria for peer assessment and feedback as a mechanism of elicitation. Indeed, we consider that both constructing criteria for peer assessment and performing microteaching could be powerful supports to challenge participants' implicit theories in a protected environment. These are the focus of the next section.

1.3 Microteaching

Microteaching is a short duration teaching episode, often around 5–15 min [14, 15]. It is a common practice used for teacher education [16]. In theoretical terms, microteaching has been presented as an efficient and effective technique in teacher training programs, because the simulated practice context gives a teaching experience to be aware of the skills of which teaching is composed. Student teachers can focus their attention on defined aspects of teaching, removing the problem of control or discipline that would be distracting with real students. Indeed, video recording the microteaching episode, peer and tutor feedback to stimulate self-analysis is recommended [15]. Similarly, observing, analyzing and discussing classroom performance could help student teachers to see themselves from a different perspective [16]. In general, microteaching provides a simulated situation to develop confidence and skills in managing a lesson, critiqued mainly by other student teachers or colleagues [15].

Microteaching in pre-service science teaching was part of a study on the teachers' perceptions of microteaching performances in connection with their beliefs about teaching science. Results showed that teachers' beliefs, rather than instructor or peer-based assessments, served as the primary determinant by which they perceived personal success in microteaching [18]. Similarly, using video in teacher education can increase student teachers' ability to apply the knowledge gained during training [19]. Recently, great interest has been shown in the processes of reflection in the sharing of video in the teaching community [20]. Personal relevance in a video is perceived to play an important role in the process of in-depth analysis and can increase awareness in the reflection [21, 22]. However, video is not effective in itself [23]. To be useful, it must be embedded in appropriate instructional contexts and have adequate scaffolding for critical thinking about the practice [20]. Although the main critique of the microteaching setting is its artificialness -it would not be sufficiently comparable to the classroom for transfer of skills- [25], all previous work recommended it as a valuable technique to prepare teaching skills, sometimes even the most effective [14]. Future studies should specifically focus on student teachers' predetermined criteria or conceptions for assessing microteaching in order to increase understanding on it [17].

1.4 Constructing Criteria for Peer Assessment Processes

Communicating information about performance criteria provides a basis for the improvement of that performance [24]. Each student should also be able to take the responsibility to make critical judgements about the performances of a peer applying the appropriate criteria [26]. However, conducting peer assessment and giving feedback is a complex skill that needs to be developed.

Peer feedback has been used extensively in many different fields and is considered a reliable and valid approach to assessment and teaching [27]. Peer feedback can be more timely and individualized than instructor feedback, encourage students to take increased responsibility for their progress, broadening and deepening reflection [28].

In the current research, peer assessment and feedback were applied through microteaching episodes in a peer assessment and feedback course.

2 Methods

2.1 Aims of the Study and Participants

The research aim was to explore implicit theories about explanations for the science classrooms in three groups of student teachers and to describe possible differences related to participants' science knowledge, measured by the number of science courses taken. The design was exploratory and descriptive. Qualitative techniques were used to gather and interpret the implicit theories. A social constructivist paradigm was adopted to understand how knowledge was created and transformed by groups [29].

The participants were 20 student teachers, 25 years old on average (min.23, max.28). They represented low and lower-medium socioeconomic status, had similar practical teaching experiences before (from zero up to a few weeks) and came from an urban zone of Santiago, the capital of Chile. Purposive sampling was carried out to select participants from universities that offer diverse numbers of science courses as part of their compulsory teacher education program, as shown in Table 1.

Table 1. Groups' characteristics.

Characteristic	University 1 (U1)	University 2 (U2)	University 3 (U3)
Science courses	14	9	4
Group size	6	8	6

2.2 Design of the Training

The participants joined voluntarily in a ten-session course as Fig. 1 summarizes. The first part included assessment of videos. Later on, the participants simulated and peer-assessed their microteaching episodes, taking the role of pupils and teachers. They constructed instruments for peer feedback in the second round of microteaching.

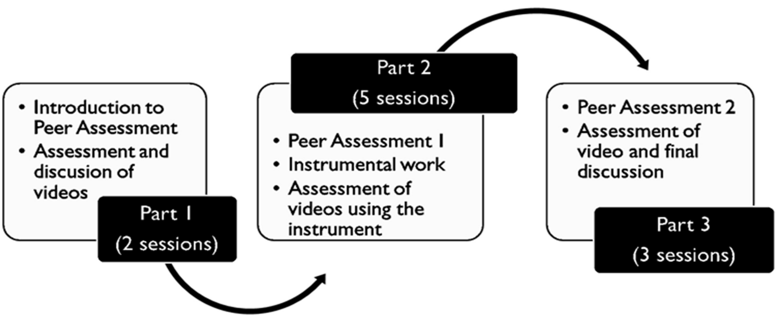

Fig. 1. Schema of 10-session peer assessment and feedback microteaching course.

2.3 Data Analysis

Implicit theories about explaining for science classrooms were elicited through the construction of assessment criteria, giving and receiving feedback. Thematic and content analysis were used to analyze the sessions transcribed. The steps used were: familiarizing with the data, generating initial codes, searching for themes, defining, reviewing and naming themes. This process involved a constant moving back and forward within the entire data set, as well as generating priorities. The results are presented and organized for each of the three groups (U1; U2 and U3) in the next section.

3 Results

In the U1 group, the implicit theories that embodied the peer assessment and feedback instrument construction (Table 2) were associated with constructivist theory applied to teaching science. The participants valued the explicit inclusion of diversity approaches in addressing the topic being explained, for instance from gender, cultural, ethnic, inter- or intra-individual differences. Likewise, reaching consensus on the scientific terms used in the explanations between the teacher and the students was relevant. The contextualization of the content appeared relevant for students' conceptual understanding, which meant putting the content in more concrete, simpler or wider elements connected with the concept. This allowed linking the explanation with what the students already knew. The correct connections between the concepts in the explanations were also mentioned as useful to support conceptual understanding, as well as links, similarities and differences between the explanation and students' everyday life. The good explanations, in their view, used students' prior knowledge and answers, which implied explanation as a transforming vehicle of students' ideas. Examples are good for explaining when they illustrate the content, are pertinent and familiar to the students and their experiences. Finally, the emphasis on the students' notes during the explanation was seen as a way of formalising the knowledge learned.

The teachers from U2 created a rubric (Table 3) based on the idea that every explanation constructed for science teaching could work as a model of the scientific concept or phenomenon being explained, and this character should be communicated to the students. The implicit theory here was that there are many ways of representing knowledge and explanation is just one of them. The first three criteria identified the moment of the lesson when the explanation appeared, as well as its function (such as motivational, demonstrative, explanatory or evaluative), and the percentage of the lesson time used to explain. Within the quality criteria they mentioned -as the U1 group- the links with students' prior knowledge had priority. The implicit theory was connecting students' ideas with the proposed model of the concept, but this was positive only when the teacher explicitly used the prior knowledge in the explanation. The participation of the students in the explanation was another important criterion. It elicited student teachers' views about the constructive process of explanations in science, which was flexible to enable integration of students' questions, ideas, etc. The accuracy of the explanation also appeared. This group thought that a teacher who

Table 2. Student teachers' rubric for peers' explanations assessment U1

Criterion	Not achieved	Half achieved	Achieved
1. Diversity approach: how the teacher explicitly teaches topics from a diversity approach	The teacher does not include address any from the diversity approach	The teacher includes in the explanation a topic from the diversity approach	The teacher approaches a topic from the diversity approach giving examples that globalize it or refer to how the diversity enriches the concept understanding
2. Terms usage: How the teacher gives meaning to the concepts	Most of the terms the teacher uses in the explanation do not have meaning got by consensus	The teacher gives a definition of the terms without exploring the students' prior knowledge	The teacher explores in students' prior knowledge about the terms being used, making them participate, correcting the mistakes and enhancing the successes
3. Contextualization: How the teacher presents a general context to introduce the explanation	The teacher does not contextualize the explanation	The teacher asks to the students to contextualize the explanation but does not declare the context	The teacher contextualizes the explanation in a simple way, interacting with the students and presenting them a concrete context
4. Link with other concepts: How the teacher links the concept with other scientific concepts	The teacher does not link the concepts, or the link is conceptually incorrect	The teacher links some concepts, but the link does not support the concept understanding or it is a not clear link	The teacher establishes a clear and conceptually correct link between two or more concepts, and it supports the concept understanding
5. Link with everyday life: How the teacher links the concept with elements from the students' everyday life	The teacher mentions a link with the students' everyday life, but does not explain the link	The teacher mentions a link between the concept and the students' everyday life but only for a memory function	The teacher mentions a link between the concept and the students' everyday life mentioning similarities and

(*continued*)

Table 2. (*continued*)

Criterion	Not achieved	Half achieved	Achieved
			differences between both without losing the focus
6. Prior knowledge: How the teacher links the concept with students' knowledge	The teacher does not gather students' prior knowledge	The teacher gathers students' prior knowledge but does not use explicitly to explain	The teacher gathers students' prior knowledge and uses it explicitly to explain, linking it with the concept explained
7. Questions: How the teacher uses different type of questions and poses them to the class	The teacher does not ask questions during the explanation or they are always closed	The teacher asks open and closed questions but poses only to a student or group, or does not wait for the answers	The teacher asks specific open and closed questions and poses them widely to the class
8. Answers: How the teacher manages the students' answers	The teacher does not do anything with the answers or always says "good"	The teacher gathers answers but integrates only the related answers to the question	The teacher integrates the answers, corrects the errors or allow students realising and self-regulate
9. Examples: how the examples with the explanation are	The explanation present examples non- pertinent to the concept or no examples	Examples are ambiguous, not close to the students or do not illustrate the concept	The teacher uses examples pertinent to the content, familiar to the students, accurate and illustrative
10. Taking notes: Whether or not the teacher encourages it	The teacher doesn't encourage students to take notes during the explanation	The teacher encourages students' notes but does not verify if they do it	The teacher encourages students to take notes and verifies if they do it during the explanation

explains correctly and answers all the students' questions is better than the one who is explaining correctly but leaving questions unanswered. Besides, this group of participants highlighted the importance of the clarity of the explanation, which was connected for them with the conceptual clarity the teacher had about the scientific concept. Their idea was that, if the teacher has clarity about the content knowledge (no mistakes when explaining), the explanatory model will be enriched. Otherwise, unclear content knowledge is unlikely to produce a good explanation through the model.

In the U3 group, the analysis of the construction of their instrument (Table 4) indicated it could be assumed they had a simpler view about explanations in science.

Table 3. Student teachers' rubric for peers' explanations assessment U2

Criterion	Indicators		
1. Moment	Beginning of the lesson	Middle of the lesson	End of the lesson
2. Observable function	Motivational: The teacher promotes the students' motivation	Demonstrative: The teacher explains nature elements through examples	Explanatory: The teacher explains phenomena or processes that occur in nature
	Evaluative: The teacher evaluates students' knowledge to challenge their prior theoretical knowledge	Other	Other
3. % of time used for expl.	0–33% of the lesson	34–66% of the lesson	67–100% of the lesson
Criterion	Not achieved	Half achieved	Achieved
4. Integrating students' prior knowledge	The teacher neither gathers nor identifies the students' prior knowledge about the content or the model presented	The teacher gathers and or identifies the students' prior knowledge about the content or the model presented, without linking them with the model	The teacher gathers and or identifies the students' prior knowledge about the content and links explicitly the prior ideas with the explanation or model
5. Reference to explanation as a model or representation	The teacher does not refer implicitly or explicitly the model used to explain is a representation of the reality and, but assumes the model is the reality	The teacher refers implicitly or explicitly the model used to explain is a representation, without mentioning implicitly or explicitly the existence of other models to explain, or that it is a provisional model	The teacher refers implicitly or explicitly the model used to explain is a representation of reality and there are other models to represent the content
6. Students' interaction with the explanation	The teacher does not make students interact with the explanation	The teacher achieves partial interaction between the students and the model, because there are doubts about the explanation and its uses	The teacher achieves student interaction with the model through the students' participation in the explanation of the model or questions

(*continued*)

Table 3. (*continued*)

Criterion	Not achieved	Half achieved	Achieved
7. Scientific accuracy	The teacher does not explain correctly, causing conceptual mistakes in the students	The teacher explains correctly, but making mistakes when answering students' questions, or the teacher does not answer all the question	The teacher explains correctly and answers all the questions raised from the students
8. Conceptual clarity	The teacher does not have a conceptual clarity, which causes making mistakes when using the model	The teacher has a medium clarity about the concept being explained at the moment of using the model	The teacher has plenty clarity about the content being taught, which enhances the usage of the model

A few elements were similar to the other two groups of teachers, but teachers from U3 presented less sophisticated ideas, which were more difficult to transform into criteria.

For these teachers, the use of examples in the explanation was the most important element in defining its quality. After questioning about the characteristics and applying the criteria, it was observed that good examples for them were: familiar or close to the students' experience, as concrete as possible and related to the scientific concept being explained. The connection with students' prior knowledge also emerged largely in this group's discourse, as in the other two groups. Here, the clue was gathering what students already knew through questions, and linking this knowledge with the concept being explained. For this group, good questions are posed to the entire class without giving priority to one student or a group of them for particular reasons.

A different aspect of explanations that appeared in this group and not in the others was the sequence and conciseness of the explanation. They mentioned the explanation should have neither unnecessary nor missed elements, but it must have a connective thread. The implicit theory appeared to be making the connection between both aspects; if there are missed elements the thread would be broken, and only if each part of the explanation connects to another would a good sequence be established. Isolated elements not connected with others would be unnecessary parts for the explanation.

In terms of the accuracy of the explanation, the U3 teachers asserted that the teacher must handle content knowledge. The way in which they referred to this was is in the precision of the explanation or when the teacher was not repetitive, because redundancy meant for them the teacher was staying only in his or her 'safe place'. Another related element was what the teacher did with students' answers. The participants mentioned clearing the conceptual mistakes and integrating them in the explanation as relevant pedagogical actions. Nevertheless, in their discourse, the teacher needed to have good content knowledge to be able to correct student misconceptions. Thus, both criteria were clearly connected.

Finally, this group mentioned collaborative work as an important criterion in the quality of conceptual explanations. By collaborative they meant constructing the

Table 4. Student teachers' rubric for peers' explanations assessment U3

Criterion	Not achieved	Half achieved	Achieved
1. Examples usage: Quality of the examples the teacher gives when explaining	The teacher does not use examples when explain or the examples used are not related with the concept being explained	The teacher uses concrete examples that are related with the concept, but they are not close to student's experience or knowledge	The teacher uses concrete examples, related with the concept and close to students' experience
2. Prior knowledge: How the teacher relates the concept being explained with the students' prior knowledge	The teacher does not gather students' prior knowledge or ideas	The teacher gathers students' prior knowledge or ideas but does not use them explicitly to explain	The teacher gathers students' prior knowledge or ideas and uses it explicitly to explain, linking them with the concept
3. Questions: How the teacher different type of questions and poses them to the class	The teacher does not ask any question during the explanation	The teacher opens a moment to ask questions (open and closed), but they are directed only to a student or a group	The teacher opens a moment to ask questions, directing them widely to the students
4. Sequence and succinctness	There is not a conductive tie in the explanation, or it is interrupted because more than one part of the explanation is missed or unnecessary	Each part of the explanation conducts to the next one (conductive tie), but there is one part of the explanation missed or unnecessary	Each part of the explanation conducts to the next one (conductive tie), and there is any part of the explanation missed or unnecessary
5. Accuracy/Conceptual knowledge	The teacher does not handle the concepts being explained, there is redundancy, mistakes or he induces conceptual mistakes in the students	The teacher handles the basic concepts, but when explaining is not accurate (there are inaccuracies)	The teacher demonstrates handling the concepts because the explanation is accurate and there are not mistakes

(*continued*)

Table 4. (*continued*)

Criterion	Not achieved	Half achieved	Achieved
6. Answers management: What the teachers does with the students' answers	The teacher does not do anything with students' answers or says "good" independently of the quality of the answer	The teacher integrates only the answers that seem correct for him, or does not correct the inaccuracies in the student's answers (they keep the mistake)	The teacher integrates the answers related with the explanation and corrects the errors, clearing the conceptual mistakes
7. Collective work with concepts	The teacher does not do any type of collective work with the concepts	The teacher works collectively a concept	The teacher works a concept, collectively giving it a shared meaning

explanation between the teacher and the students and also between the students. This could be achieved through activities that allowed collaboration which reflected a more flexible view about the nature of the science knowledge and its construction.

Through this process of product analysis, it was possible to observe the group of student teachers' theories varied according to the university they belonged to, then, perhaps by the program views. There were not observable differences in the participants' implicit theories which might be due to the amount of science courses they have had. This is assumed because the three groups referred to elements related to scientific knowledge in an equally relevant manner. Although all the groups adhere to constructivist theories of teaching science, at the moment of deciding why a peer simulated explanation was better, the groups U1 and U2 presented more elements than U3. In this last group, the participants' implicit theories included broader elements, not only useful to analyze and assess explanations for the science classroom, but for the whole lesson and subjects, such as collaborative work, teachers' feedback, etc.

4 Discussion

The instruments generated by the participants were considered as the participants' products of their implicit theories. Working on a concrete artefact for each group helped the participants to reorganize their knowledge from the implicit to the explicit, so that it could be observed and influenced [1, 19]. As the participants engaged in both roles –teacher and simulated student, giving and receiving feedback- empathetic feelings necessary for creating a challenging but protected learning environment were developed [12]. We think it is in this type of environment where new meanings can be explored and negotiated through reflective thinking.

It was possible to observe that the three groups of student teachers' implicit theories were different, perhaps because of the teacher education programs in which they were enrolled. Nonetheless, there were no differences in the mentioned elements related to science knowledge in the arguments which might be have been due to the differences in the amount of science courses the participants had had. This is remarkable because explanations for the classroom are highly dependent on the content, processes or concepts being taught [6]. The groups from U1 and U2 presented more relevant elements than U3, and in this last university group the implicit theories about the explanations for the science classroom were less sophisticated, simpler and less articulated than in the others. However, there were two common points between the three groups of student teachers: the use of examples and the interaction between the teacher and the students during the explanation. Elements such as analogies, metaphors or simulations, or using mistakes as a learning opportunity appeared indistinctly, which were relevant for teaching science constructively.

The process of making explicit the implicit theories of student teachers through simulated teaching practices in microteaching can be seen through the lens of developing pedagogical content knowledge (PCK). This is an amalgam of content knowledge transformed by the teacher into a form that makes it understandable, including analogies, illustrations, examples, explanations and demonstrations to reformulate the subject knowledge and make it understandable to the students [30]. The problem is how to enhance its development when no teaching experience in real classrooms is available? In the present research, simulating teaching and observing peers' teaching in several microteaching episodes for giving and receiving feedback, gave an opportunity to develop the roots of PCK because explanations are a form of transformation of the science concepts for teaching purposes. We believe that PCK is embedded in details of classroom experiences, especially in those that present difficulties, in which personal theories are put into action. Thus, peer assessment and feedback of microteaching might be useful for exploring and sharing in early teacher education.

This study involved the construction of assessment criteria as a way of negotiating and constructing collective meaning about practices for the classroom. From this perspective, the discussion allowed negotiation of meaning, and the rubric constructed per each group allowed internalization of assessment criteria as a personal parameter for reflective learning about their own practice, and perhaps, a source of internalised self-critique for future practice.

5 Conclusion

We analyzed implicit theories about explanations for the science classroom held by student teachers and described their differences. Although we are aware of the difficulties in generalizing the results, given the qualitative nature of the study, we strongly believe this is a methodological advance in terms of the use of microteaching, not only for putting theories into practice but for eliciting and challenging student teachers' deeply rooted ideas on teaching for the science classroom. The results confirm the centrality of reflection, useful for enhancing skills and teachers' thinking. Moreover, peer assessment and feedback, aided by the construction of an assessment tool such as a rubric, was shown to be useful for constructing and negotiating meaning. Reflection through peer assessment was central and the video evidence supports this, in the light of the creation of assessment criteria to assess not only their peers' but also their own strengths and weaknesses in a self-critique opportunity. This is one of the projections of the analyses conducted here. We argue that being aware of this might develop the roots of PCK during early teacher education programs, even with no real teaching experience undertaken by the student teachers.

The present research expanded the role of simulated teaching practice during teacher education, as well as enhancing the negotiation of meaning for making explicit student teachers implicit theories. The internalization of the jointly constructed achievement criteria might also enhance improvement in teaching performance, based on a reflective rather than imposed process. Future research should extend and broaden these findings.

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Teacher Training, Mentoring or Performance Support Systems?

Roberto Araya(✉)

Centro de Investigación Avanzada en Educación, Universidad de Chile, Periodista Mario Carrasco 75, Santiago, Chile
roberto.araya.schulz@gmail.com

Abstract. A major challenge in education is how to improve teaching. This means improving teaching so that all students effectively achieve the levels of performance stipulated in the curriculum and that they do so within the specified timeframes. This goal is particularly difficult to achieve in schools with students of low socioeconomic status. However, measuring the quality of instruction is not a straightforward task. This is partly due to a lack of rigorous and regular data on student performance gathered by independent third parties. On the other hand, there are several alternatives for improving teaching: teacher training, teacher mentoring programs and support systems to boost teacher performance. Our study looks at eight years of data on national standardized test scores for every school in a low SES district. We found that the effect size of a Performance Support System is larger than the benchmark effect sizes for teacher training and teacher mentoring programs.

Keywords: Performance Support Systems · Teacher training
Teacher mentoring programs · Effect sizes

1 Introduction

A major challenge in education is how to improve teaching. This challenge has two critical components. Firstly, it is not easy to measure the quality of teaching. Take for example quality assessments by principals and peers. In 2009 [1] found that, in most U.S. districts, less than 1% of teachers were rated as unsatisfactory. In other words, on paper, practically every teacher is satisfactory. However, 81% of administrators and 57% of teachers could identify a teacher in their school who they considered to be ineffective. The authors named this paradox as the Widget Effect. They describe this failure as the tendency of school districts to assume that classroom effectiveness is the same from teacher to teacher. This failure may be caused by inadequate evaluation systems. A reform in evaluation procedures could therefore help solve this problem. However, in a 2017 study, [2] analyzed teacher performance ratings across 24 U.S. states in which major reforms had been made to the teacher evaluation system. They also found that, in the vast majority of these states, the number of teachers rated as unsatisfactory was still less than 1%.

One significant alternative is to measure teacher knowledge and teaching practices. However, the focus should actually be on measuring student learning. In this sense,

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rigorously measuring student gains is a difficult and very expensive process. For example, according to [3] the 1966 Coleman Report, often described as "the largest and most important educational study ever conducted", cost approximately USD $1.5 million. To put this into perspective, the equivalent cost in 2016 would be USD $11 million. Furthermore, there are several factors at play when it comes to calculating the effect. This includes factors such as the type of assessment, the timing, critical contextual information, and the independence of the evaluation team from the program coordinators. For example, according to [4] there is a significant difference in the average effect sizes that are found for different kinds of measurements using achievement tests. In this sense, there are three types of measurements: (i) standardized tests on a broad subject matter, (ii) standardized tests that focus on a more specific topic, and (iii) specialized tests developed specifically for an intervention (typically developed by the researchers). Larger effect sizes have been found with specialized researcher-developed tests (median 0.34 and standard deviation 0.55 for elementary school), which are presumably more closely aligned with the intervention that is being evaluated. The effect size of interventions measured with standardized tests focusing on a specific topic tend to be smaller (median 0.17 and standard deviation 0.42 for elementary school). Finally, the effect size of interventions measured using more general standardized tests are much smaller (median 0.07, standard deviation 0.27 for elementary school). In this paper, we use results from a national standardized test in mathematics (SIMCE). This is a broad test that is designed to cover the contents of the national curriculum for mathematics.

Secondly, there are several strategies for improving teaching. The most common strategy is teacher training. However, measuring the impact of teacher training on the quality of education is not a straightforward task. Several studies show that teacher training can lead to significant changes in terms of teaching practice. Despite this, teacher training has not been shown to have any impact on student performance. For example, a recent study of a year-long teacher training program for math teachers revealed significant improvements in the teachers' content knowledge, as well as changes in their teaching practices [5]. However, the study also found that there was a negative effect on student performance on state-level assessments. In a 2010 study by the same authors [6], no improvement was found in student performance, despite there being a change in teaching practices. In this case, the authors analyzed an intervention at 77 moderately high and highly vulnerable schools from 12 districts. Each teacher received 68 h of training over a number of sessions throughout the year. The training focused on teaching fractions and involved three different teaching strategies: having students comment on the results or procedures of others, having students use representations, and having them justify their results. Furthermore, each teacher was accompanied in the classroom for a total of 10 days following the initial 5-day training session. These follow-up sessions lasted for two days and were spread out across the year. The results of the study revealed that the teachers did not improve their knowledge of fractions, did not use representations more frequently and did not request more justification from their students. In fact, the teachers only slightly improved in terms of having students comment of their peers' results. However, this change did not improve the students' performance in fractions. This is despite the fact that the teachers in the control group only received 12 h of training in mathematics for the year, and not specifically in fractions. Another large meta-study of randomized controlled trials of teacher training programs [7], revealed that structured professional development programs (highly prescriptive programs with follow-up and support) have an average effect of 0.05 standard deviations on student gains. A recent summary of research by the U.S. Institute of Education [8] analyzed 910 studies on the effectiveness of different approached to professional development in math teaching. This comprehensive literature review concluded that "until more causal evidence becomes available, schools and districts must supplement the limited evidence of effectiveness with their best judgment. Schools and districts should be encouraged to rigorously evaluate professional development approaches themselves and, when possible, to report the findings publicly to build up the knowledge base on the topic".

Are there any other strategies that might have a more significant effect on improving the quality of teaching? One such strategy is mentoring programs, also called the "Third Way" [9]. This involves experienced full-time teachers, who are carefully-selected and trained to be mentors, giving support to newly-qualified teachers during their first one or two years of teaching. For example, (Schmidt et al. 2017) showed that after one mentor worked with 15 newly-qualified teachers for two years, the program obtained an average effect of 0.15 standard deviations in terms of student gains. This is a very large effect size when compared to the effects of teacher training. However, this effect was obtained with newly-qualified teachers, who are mostly likely to improve the most. On the other hand, other studies report no effect for mentoring programs, or even negative effects. This was the case with the Urban Teacher Residencies (UTRs) program in Boston [9]. This program covers a large number of newly-qualified teachers that are hired in the Boston area. Since 2008–2009, UTR accounts for about one third of all newly-qualified teachers in the district.

So, how about strategies for improving teaching among experienced teachers? One possible strategy is the use of Performance Support Systems. This kind of system supports teachers on the job and in real time. In this paper, we analyze the impact of ConectaIdeas, a cloud-based system that helps the teacher to teach more active learning classes. The system allows the teacher to pose closed and open-ended questions, teach using games, connect with other classes in real time, hold online, synchronous tournaments with several other schools, and share their experiences with other teachers. We report on 6 years of data from the system, which was implemented in every fourth-grade mathematics class at all 11 public schools in a low SES district of Santiago, Chile.

2 Methods

We study performance in mathematics at 11 schools in Lo Prado, a low socio-economic status (SES) district of Santiago, Chile. These 11 schools are all the public elementary schools that are run by the local district. One of the schools is classified as low SES by the Ministry of Education. This segment includes the lowest SES schools in the country and accounts for approximately 7% of schools in Chile. All of the schools in this segment are considered at-risk. The rest of the 11 schools are classified as medium-low SES. This segment accounts for another 20% of schools in the country. We analyze the fourth-grade students' performance on the National Standardized Math Test (SIMCE math test) between 2009 and 2016. This information covers eight years of standardized measurements at each school.

Furthermore, teachers on Treatment classes have been using ConectaIdeas, a Performance Support System since 2011 [10, 11]. This is a web-based platform where the teacher selects from a list of exercises or can ask the students open-ended questions. The teacher can review the answers online and ask students to do peer review. The teachers normally access the system through a tablet or smartphone in order to monitor the class. The system also helps the teacher to analyze answers to multiple-choice and open-ended questions. Furthermore, the system also preselects students that can act as monitors and help the teacher provide support to the other students. Using the system, the teacher assigns monitors to help their peers. They then receive feedback from the monitor, as well as from the student who received the support. ConectaIdeas also provides a math game, where the teacher selects the area of the curriculum to be used as the focus of the game. Students can play the game alone, or compete against a classmate. There is also the option to host inter-class or inter-school tournaments [12].

Some of the schools in this study had two fourth-grade classes, while others only had one. Over the years, some of the schools also went from having two fourth-grade classes to having just one. This means that the data comes from a total of 122 classes. Of these classes, 80 of them were under treatment, 16 in 2011, 16 in 2012, 11 in 2013, 11 in 2014, 13 in 2015, and 13 in 2016. The remaining 42 classes had gaps at different stages during this period. Of these 42 classes, 32 of them did not work with the system during 2009 and 2010. Furthermore, five of these classes also failed to use the system in 2013, while five of them did not use it in 2014. These 10 classes belong to three schools that decided not to continue with the program during those years. However, all of the schools decided to return to the program in 2015. Previous analyses [13, 14] had considered only one or three years of experience with the Performance Support System. In this study, we review the impact after six years of using the system.

The government only publishes school-level data and does not release data on individual students' performance. We are therefore not able to perform a multilevel analysis. Furthermore, we cannot use the difference in difference methodology [15], since we only have one measurement per class. This measurement is done at the end of the school year. There is no pretest for each class. However, the number of classes is enough to estimate effects by comparing treated classes with untreated classes. In addition to this, the classes take the test in different years, with the average score on the national standardized test changing from year to year. We are therefore able to correct the estimate based on these yearly changes. In any case, the differences in the average are minimal, while there is practically no difference in the standard deviation of students' scores.

This study is not a Randomized Controlled Trial (RCT) as all of the schools in the district underwent treatment in 2011. Furthermore, the district was also not randomly selected. However, three schools left the program in 2013 and 2014. This is very interesting for the purposes of our assessment as it helps us to measure the impact of the treatment. However, the three schools were also not selected at random; their principals decided to leave the program. Nevertheless, they decided to return to the program in 2015 following two years of poor results. This provides another fantastic opportunity to measure the effect.

3 Results

The average scores on the fourth-grade SIMCE math test are shown for each school between 2009 and 2016 (Fig. 1). The government only publishes the average score for each school. Since some schools have two fourth-grade classes and others only have one, we calculate the average performance by weighting according to the number of classes in each school. The schools' overall average is shown as a bold line. We can see a significant jump in the average score between 2010 and 2011. This improved score is then maintained from 2011 onwards, despite a slight dip in 2013. In any case, the average in 2013 is still higher than in 2009 and 2010.

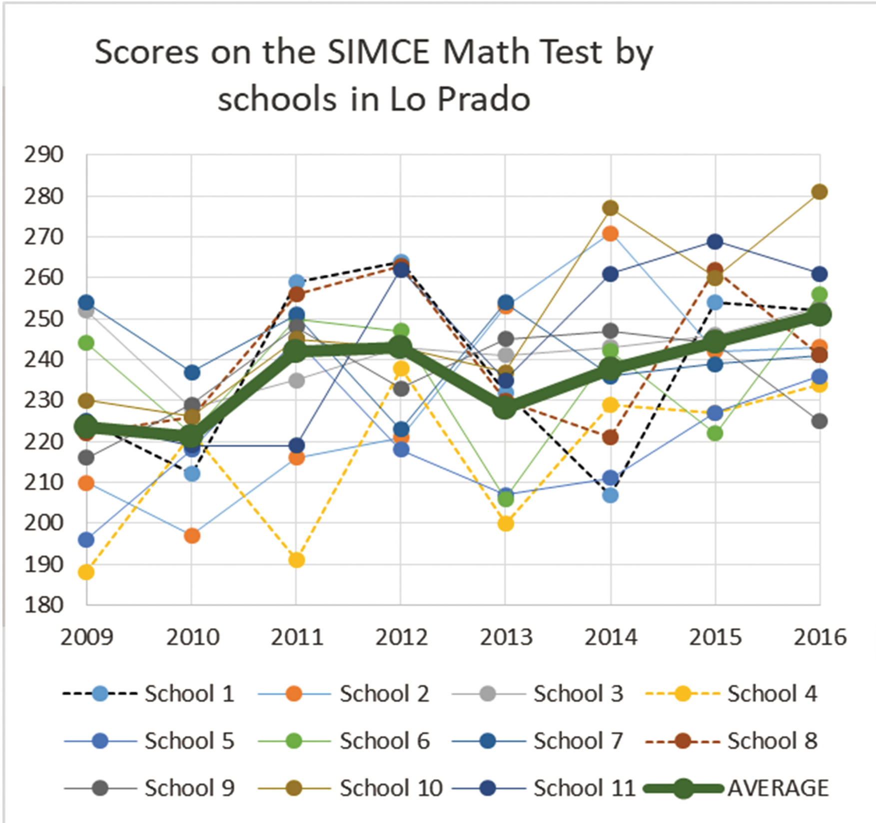

Fig. 1. Scores on the fourth-grade SIMCE math test between 2009 and 2016 for the 11 schools in Lo Prado. The overall average for all of the schools, weighted according to the number of classes in each school, is shown as a bold line. As the scores for each class are not publicly-available, we plot the overall scores for each school.

All of the schools began using the ConectaIdeas Performance Support System during the second semester of 2010. However, due to issues with their internet connection, several schools were not able to connect and use the system. The System therefore started to be used properly in 2011. Given this, we consider that treatment started in 2011. The weighted average score on the SIMCE math test for the treatment schools is shown as a continuous bold line in Fig. 2. The average of the schools with no treatment is displayed as a dotted bold line (Fig. 2).

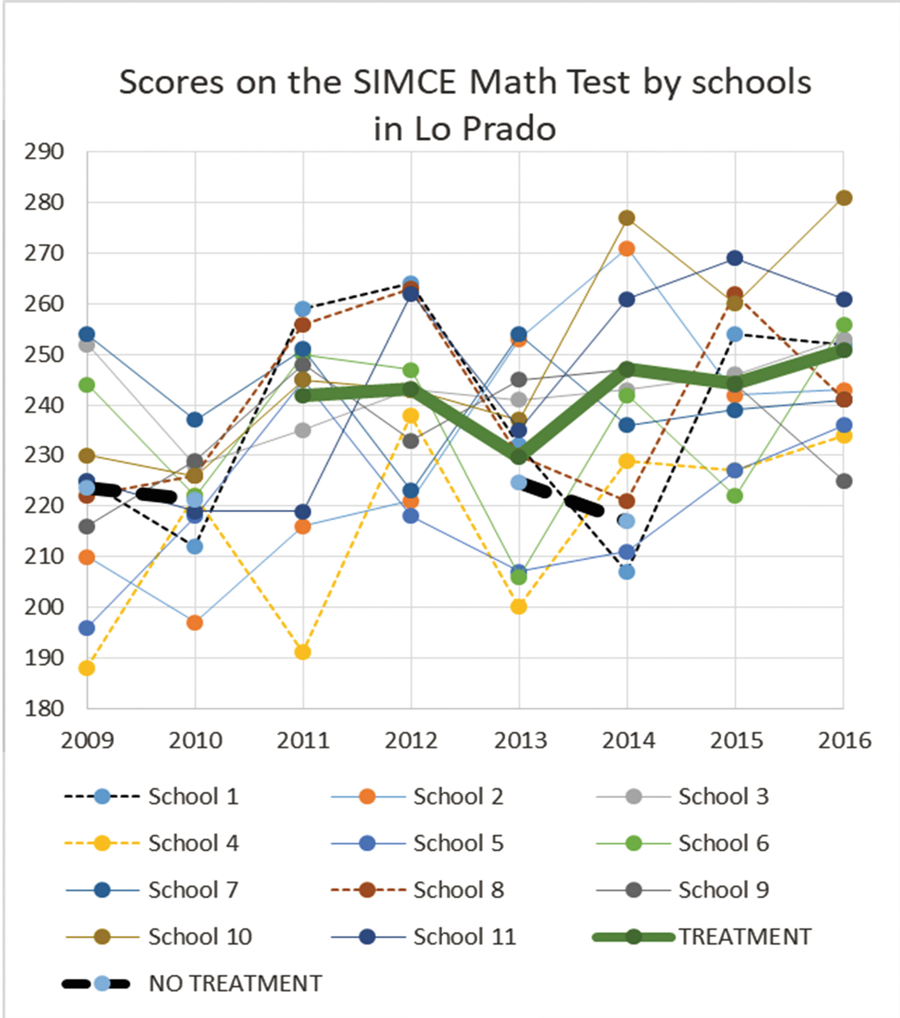

Fig. 2. Scores on the fourth-grade SIMCE math test between 2009 and 2016 for the 11 schools in Lo Prado. The weighted average score for the treatment schools is shown as a continuous bold line. The weighted average score for the schools without treatment is shown as a dotted bold lined.

Figure 2 reveals a significant improvement in the schools' performance in 2011 (i.e. the weighted average of all the schools). In this sense, there is a 20.6-point jump, which represents 41.2 standard deviations of the students' scores on the SIMCE math test. This improvement in performance is probably the effect of the treatment. The average increase in the national average for that year was only 5.9 points, while for low-medium SES schools it was 8.44 points. In 2013 and 2014, three of the schools (School 1, School 4 and School 8, all depicted using dotted lines) were not included in the treatment program as their principals decided to leave the program. The weighted average of these three schools was less than the weighted average of the rest of the schools during 2013 and 2014. However, there was also a drop in the treatment schools' scores in 2013. The gap between the treatment and non-treatment schools was 5 points in 2013, which corresponds to 0.10 standard deviations. The overall drop was probably due to the test being more difficult, since the whole country dropped 5 points that year. This was also the case for low-medium SES schools. However, the drop-in score by students at the non-treatment schools may have been reduced by the fact that those students used the system the previous year as third graders. This is because the treatment was for both third and fourth graders. However, the scores for non-treatment students continued to drop in 2014. A probable cause of this is that these students did not use the system in 2013 and were therefore without the treatment for two consecutive years. Meanwhile, the treatment students recovered and improved their scores. Subsequently, the gap in 2014 increased to 30.1 points. This gap corresponds to 60.2 standard deviations.

Another possible explanation for the drop in the scores at these three schools in 2013 and 2014 could be the schools' management and leadership. However, as it involves three schools, the probability of mismanagement for two years at all three is quite low. Nevertheless, it may well be the case that the ineffectiveness of the principals in question led them to leave the program. However, the data on sixth-grade SIMCE Math scores for 2013 and 2014 also reveals that these three schools had reasonable good results, unlike the fourth-grade SIMCE Math scores The results on sixth grade of these schools were even better than their results in 2015 and 2016. Thus, the bad performance of the fourth graders on those schools in 2013 and 2014 was probably not due to management. The sixth-grade SIMCE tests only began in 2013 and therefore no data is available for previous years.

The average SIMCE math score for the 80 treatment classes was 242.8, whereas for the 42 non-treatment classes it was 222.2. Furthermore, the standard deviation among students in the country is 50, and in Lo Prado is 50 too. Over the years, there have been some minor variations in the national average score on the SIMCE test, as well as the average score for low SES schools. However, the national average between 2009 and 2016 has not changed by any more than 4 points, while the average for low-medium SES schools has not changed by any more than 10 points. When correcting for these yearly variations, the difference between the treatment and no treatment classes is 14.8 points. This difference corresponds to an effect size of 0.30 standard deviations.

It is interesting to observe that the average score on the SIMCE math tests for the 32 classes that did not use the system in 2009 and 2010 was 222.5. This is practically the same as the average for the 10 classes that did not use the system in 2013 and 2014 (220.9). In that sense, the classes that did not use the system in those years did not improve on their historic performance on the SIMCE math test.

4 Conclusions

In educational practice, it is not always possible or affordable to design experimental studies, such as randomized controlled trials. However, sometimes, new treatments are introduced to a large population. Then, it makes statistical sense to capitalize on the historical data that is generated whenever possible. According to [3] "Once a set of teachers or students are chosen for an intervention, the state databases could be used to match them with a group of students and teachers who have similar prior achievement and demographic characteristics and do not receive the intervention. By monitoring the subsequent achievement of the two groups, states and districts could gauge program impacts more quickly and at lower cost. The most promising interventions could later be confirmed with randomized field trials" p. 8.

In this paper, we have analyzed the data generated by a practical implementation of a program that introduces a Performance Support System. All schools in a low SES district received a new treatment in 2011. Furthermore, two additional events are very useful for estimating the effect of the treatment. Firstly, three schools (i.e. 10 classes) left the program for two years between 2013 and 2014. Secondly, these schools subsequently returned to the program in 2015 and 2016.

By comparing the performance of the treatment schools with the non-treatment schools over the years we are able to estimate an effect size. Under these special circumstances, we can estimate an effect size of 14.8 points on the National Standardized Math Test (SIMCE math test). This effect corresponds to 0.30 standard deviations.

How big is that effect? Rigorous studies [16] using randomized controlled trials and measuring gains in student performance reveal that the upper quartile of teachers in terms of added value (i.e. student gains on standardized test) is 0.33 standard deviations above the added value of the lower quartile. In other words, if we were to implement a radical (and politically impossible) strategy of firing all teachers in the lower quartile and replacing them with teachers of same quality as those in the upper quartile, we could expect to achieve an effect size of 0.08 standard deviations. Therefore, an effect size of 0.08 standard deviations seems to be the upper limit when it comes to teacher training. The effect size that is estimated for the ConectaIdeas Performance Support System is therefore much higher than the upper limit for teacher training. It is also higher than the reported effect size of mentoring programs [9, 17, 18].

Another critical issue is the need to understand this effect size in practical terms. Is the estimated effect large enough to be substantially important or relevant to policymakers? [19]. One strategy is to compare the effect with the typical increase in student learning over a whole year, as measured by standardized tests. This is another type of benchmark. Here, the effect of the intervention is compared to the natural growth in academic achievement that takes place over the course of a year for an average student. For example, according to [4, 19], the annual achievement gain on a National Standardized test in fourth-grade mathematics is 0.56. We do not have statistics on natural growth in Chile. These would be very difficult and expensive to obtain as the SIMCE math test is only sat by certain grade levels. Unlike in other countries, such as the U.S., in Chile there is not a standardized test for every grade level. The SIMCE test is a national test that is traditionally only sat by fourth graders, eighth graders and tenth graders, as well as now by sixth graders. However, if we assume similar natural growth as in the U.S. then the intervention with the ConectaIdeas Performance Support System, which had an estimated effect size of 0.30, represents 54% of the annual natural achievement gain for fourth graders. This is an enormous gain. It is equivalent to the gain made in math through half a year of schooling.

The results obtained so far are very promising. However, this is not an RCT study and involves only one district. As [20] recommends "…more experimentation and evaluation is needed. The only way to know what works and what does not work is by innovating, piloting, evaluating, and learning".

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An Academic System Based on Ontological Networks to Support the Inference of New Knowledge in Micro and Macro Curriculum in Higher Education

Roberto García-Vélez[1,2](✉), Jorge Galan-Mena[1], Vladimir Robles-Bykbaev[1,2], Martín López-Nores[2], Fernando Pesántes-Avilés[1], and Daniel Calle-López[1]

[1] GI-IATa, Catedra UNESCO Tecnologías de Apoyo Para La Inclusión Educativa, Universidad Politécnica Salesiana, Cuenca, Ecuador
{rgarciav, jgalanm, vrobles, fpesantez, dcallel}@ups.edu.ec

[2] AtlantTIC Research Center for Information and Communication Technologies, Department of Telematics Engineering, University of Vigo, Vigo, Spain
mlnores@det.uvigo.es

Abstract. The Institutions of Higher-Education (IHE) seek to answer to the new ways of understanding and projecting the higher-education materialized in a graduate's profile. Before this challenge the educational models take principally the theoretical - practical references of the critical pedagogy, the constructivism and the collaborative learning. Though there exist several offers of administration of the knowledge, which have formalized the structure organizational of the academic institutions in ontologies, considering the actors (student-teacher), the evidences that the academic process produces and since they relate among yes. None divides and explicit the development that the actors of the ecosystem take across the time. Our offer is the construction of an ontological network academician, as instrument of support to the academic body and for centralization of the information. For which we realize a process of reengineering of institutional relevant documents, as the academic record of the students, in each of your facets of learning. In addition, we interview specialists in the area and re-use ontologies of academic domain, shaping this way a strong base of knowledge.

Keywords: Higher-education · Ontological network · Semantic technologies

1 Introduction

The IHE generate big volumes of academic information, that could be reused as a feedback inside the academic system. This process will allow us to be able to acquire relevant knowledge on the functioning of the academic ecosystem, for with it is able contextualize the new way of understanding and projecting the IHE across a profile of updated student. The principal reasons that limit the power to acquire the implicit

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knowledge that contains this information are, the diversity of formats not structured in those who are, or to that the information is in different databases or digital not connected repositories. Several offers of administration of the knowledge have developed [1, 2] relying on the formalization of the structure organizational of the academic institutions on ontologies, these approximations focus in the actors of the ecosystem (student, teacher, department, organization), the evidences that the academic process produces and since they relate between yes. These approximations cover the exterior base of the process of education, but they do not divide and not make explicit the evolution that the actors and the information of the academic ecosystem capacitating acquire across the time. Our ontological network captures the behavior in the time of the actors who intervene inside the academician's process of learning, using the paradigm of the semantic technology to have structured, understandable and accessible information. Since goal ontological language was chosen by OWL to be able to represent the whole knowledge of an explicit way, by means of axioms, relations and classes, providing an understanding to level machine. Finally, for the creation of the ontologies and the indexation of ontological academic networks the methodology managed. In the present work, the information of that of the Universidad Politécnica Salesiana (UPS) in Ecuador appears across a model of ontologies of network in the frame of established methodologies.

2 Related Work

Knowledge represents one of the most important factors within an institution, since it provides a competitive advantage. In the university domain several alternatives of ontological modeling have been presented, considering several relationships between different concepts that comprise the structure of a IHE. Among the advantages of occupying university ontology is the possibility of reusing it and integrating it into any higher education institute, facilitating efficient access and retrieval of information. In this regard, Guangzuo, et al. propose a platform architecture for e-learning called OntoEdu [3], composed of five parts: user adaptation, automatic composition, education ontology, service module and content module obtaining promising results in the concept of reusability, device and user adaptability, among others. The education ontology is described with OWL. It is worth mentioning that [4] discuss the steps for the development of a university ontology, this can be used in a particular university. The ontology was designed based on several courses offered by the university, also the coherence of the university ontology was checked with FACT ++.

There is also an approach that focuses on the process of describing information in a way that is understandable by humans and machines, with an approach that aims to stick to the semantic web to maintain a universal model on the web and allow the obtaining of better results to describe information intelligently [5]. Other approaches establish a high-level ontology, proposing that the IHE should be responsible for the initial construction of the Domain Ontology [6]. The methodology and construction processes were analyzed in depth, the resulting ontology was the result of the intervention of non-professional users. Under these principles, academics from all fields participate in the construction of ontology.

3 Development

The network ontology of the academic ecosystem has the mission to capture the behavior of the actors who intervene inside the learning process in the classroom of the IHE and to carry out it by means of a formal representation that unifies all the processes that are realized among the teacher and student under a program of studies. To be able to represent the multiple conceptualizations that arise from the academic processes and unify them one must use a formal model to be able explicit all this knowledge.

The language of the formal model who was chosen is OWL because it is a meta ontological language that serves us for the representation of the knowledge unlike with another type of more traditional representations like the model entity relation that information represents. Inside this frame of the use of a formal model who represents knowledge and the traditional models who represent only structured information, one presents a contrast due to the fact that taking the structure of the information as an example a model entity relation, only it is understandable for the designers of the above mentioned database where implicitly they know the meaning of every table and field, whereas with the formal models already we explicitly the above mentioned knowledge in something tangible by means of axioms, relations and classes, providing an understanding to level of machine. A strategy for the modeling is the use of an ontological network that is a collection of ontologies that share relations with a potentially big number of other ontologies [7]. The methodology chosen for the construction of our formal model was Neon [8] that is used for the development of ontologies and ontological networks.

3.1 Elicitation of Requirements

The methodology Neon specifies the phase of ontological requirements to know because the ontology is created, which are your foreseen uses, who are your users, and that requirements are those that must be fulfilled [9]. The process of elicitation of requirements ends with the development of the document of elicitation of requirements. The users who were defined for the development of the process of elicitation of requirements were: the experts in the domain and ontological medical instructor:

- The experts in the domain have a leaders' profile of management in the academic processes of an IHE.
- The ontological medical instructors are person's expert in the development of formal models.

In this stage a series of processes are demanded to realizing like: the identification of requirements, grouping of functional requirements, validation of requirements, extraction of terminology and frequency, all these activities conclude with a matrix of requirements like it is possible to see in the Table 1, where there is had a small capture of the most important elements discovered from an interview with the specialists by means of questions of competence, the first column represents the identifier of the meaning, in the second column the terms associated with this meaning and in the third column the code of question of competition with which the term was associated:

Table 1. Extract of functional requirements.

Code of group of term	Group of term	Code asks competence
TG4	Activity	PC4, PC5, PC19
TG41	Teacher/Pedagogue	PC1, PC3, PC6, PC8, PC9, PC4, PC7, PC12, PC15, PC16, PC19, PC21, PC22
TG52	Graduated	PC27
TG73	Curriculum/Model curricular/Plain curricular/Project curricular	PC13, PC14, PC3, PC1, PC9, PC28, PC11
TG5	Pupil/Student	PC7, PC9, PC1, PC3, PC4, PC6, PC16, PC20, PC21, PC22
TG12	Area of knowledge/Field/Field of study	PC12, PC16, PC27, PC14
TG71	Macro curriculum	PC26

Everything it is terminology was supported by the experts of the domain. All the requirements of the document are the base for the development of other phases of construction of the ontology.

3.2 Ontology Design

Departing from the principal concepts that were revealed by the process of elicitation of requirements in the interviews with the specialists we can conclude brief that taking the academic ecosystem as a specific case the UPS, can say that beginning from the exercise of classroom towards the external ecosystem the actors consist of the students and teachers, which will have different roles in the processes of classroom, it is here where there are evaluated the competences and skills that the students acquire raised in the planning of activities of each one of the subjects; every subject forms a part of a program curricular. That offer the careers according to the changes of the external environment as regulations of the organism of IHE in a country or to the same changes I hospitalize to that an educational ecosystem submits in your own organization. With this premise and the requirements, we can have a criterion to select different tactics to create the ontological network using the most suitable elements, in our case one chose to choose the reengineering of not ontological resources [10] and alignment of ontologies that were covering the concepts of the requirements to form the ontological network. In the process of transformation of not ontological resources had been provided a report of an analytical program of a matter and a report of mesh curricular, where key classes were defined for the formalization of the model, this process delivered us like gone out the ontology of the academic ecosystem (OAE) which expires with the requirements listed in the document of elicitation of requirements.

The ontology of *VIVO* [11] is an ontology directed the scientific community, which reuses ontologies like *BIBO* [12] that is an ontology to describe bibliographical information of scientific documents, *FOAF* [13] that shapes a social simple network of persons' links and groups, BFO [14] a high-level ontology that is the frame of reference to organize hierarchically the concepts that join to VIVO. Another ontology of purely academic area is FOAF-Academic [15], which extends FOAF's vocabulary to adapt it to an academic community. With the selection of the ontology of VIVO to form a part together with the ontology developed of OAE in an ontological network, there was realized a process of alignment of both ontologies, including classes, properties of information and relations of VIVO in OAE which form the links for the coexistence of both ontologies like it shows in the Table 2, taking as a general frame for OAE's development the high-level ontology BFO, since VIVO one organizes its taxonomy on this high-level ontology and facilitates the alignment of classes.

Table 2. Classes and properties of information re-used of VIVO.

Classes	Properties of objects
SKOS:Concept	VIVO:associated concept
FOAF:Person	VIVO:has subject area
FOAF:Organization	RO:bearer of
IAO:Mesaurement Unit Label	SKOS:broader concept
ERO:Student Role	VIVO:concept for
VIVO:Teacher Role	VIVO:subject area of
C4DM:Event	VIVO:date/time interval
VIVO:Course	VIVO:date/time value
	RO:has participant
	RO:has input
	RO:has output
	RO:inherents in
	RO:has member

Expiring with the requirements and the formation of the ontology they present the different cases represented in the designs of the ontology, from the part macro curricular up to the exercise of chair in the lounges of classes between teacher and student.

Since it is possible to observe in the scheme of organization curricular in the Fig. 1 we can observe like dividing from the general compendium understood as *Career* there are offered different *Curriculums* that have a component of *subjects* and of *hours* removed of the sum of hours of subject, in turn we have that every subject also have a component of subjects y de activity templates, a minimal score to approve the matter and a component of hours that is the sum of hours of the activity templates. Finally, we can see, like activity template it is composed of a component of dedicated hours control to the activity, a scale of valuation of the activity and a component of *resources* necessary for the accomplishment of the activity.

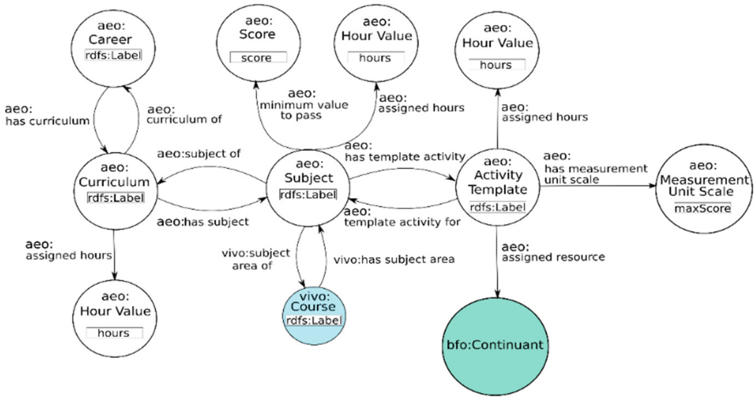

Fig. 1. Ontological scheme of organization curricular.

In the scheme of offer and matriculation of a course like it presents in the Fig. 2, the environment is described in the exercise of chair involving both the student and the teacher. Using the classes of VIVO integrated to OAE like its presents in [16]. we can describe as a *person* can have a *role* already be like a *student* or like *teacher* inside a *course* offered in an *interval of given time*, adding the *tuition* as a record of a person in a matter and the *total score* corresponding to the matter, this *total score* is the sum of the *partial scores* valued for the different activities. The *tuition status* answers to a minimal note presented in the minimal note of the subject related to the course, if the total note of the tuition expires with the minimal note at the time it will relate across is *Status* with the instance *approved* opposite case *lost*. The process of valuation of the activities forms of the Fig. 3, of which, dividing from the activity that is based on the *activity* which is based of *activity template* of the planning of the subject, there is valued the *activity developed* in the course on the part of the student in an *assessment process*, in which the teacher and the student intervenes as *assessment* and *evaluated*, this process has as aim generate notes that are in reason of the *measurement unit scale*.

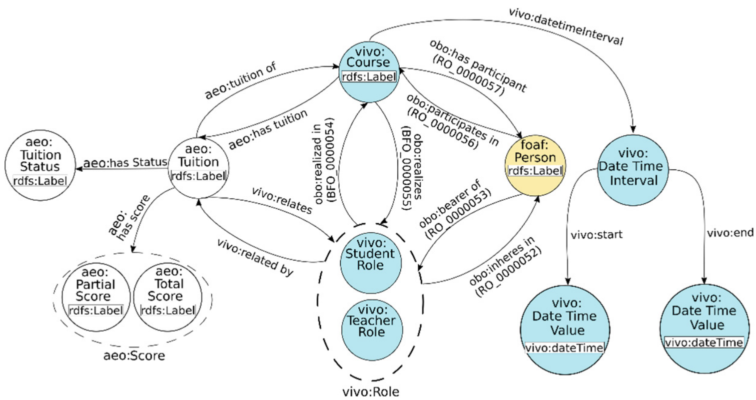

Fig. 2. Ontological scheme of offer and registers of a course.

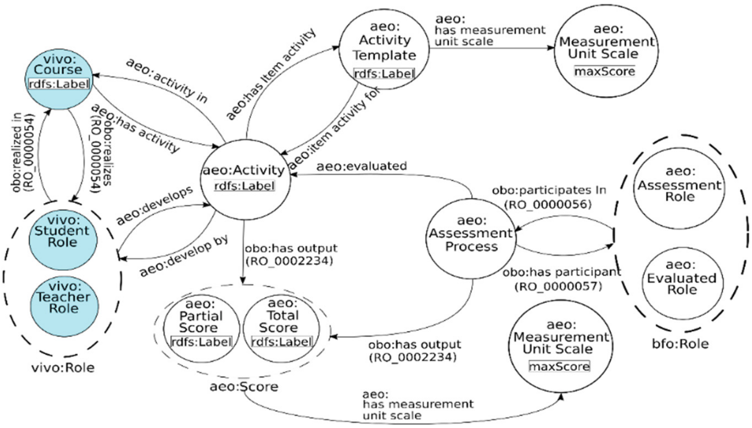

Fig. 3. Ontological scheme of valuation of activities in the course.

All these presented schemes it is possible to see them developed in the ontology OAE like shows in the Fig. 4 where one presents a capture of one display screen of ontological schemes called VOWL and they demonstrate that departing from the organization curricular from a career and his components in the subjects and activities planned it is possible to land in the exercise of chair where the immersed activities are demonstrated in the processes of valuation and that meet reflected in partial and total notes in the matriculation that they are entered define if the pupil acquired the necessary competences and he/she overcome the academic process of the course or not.

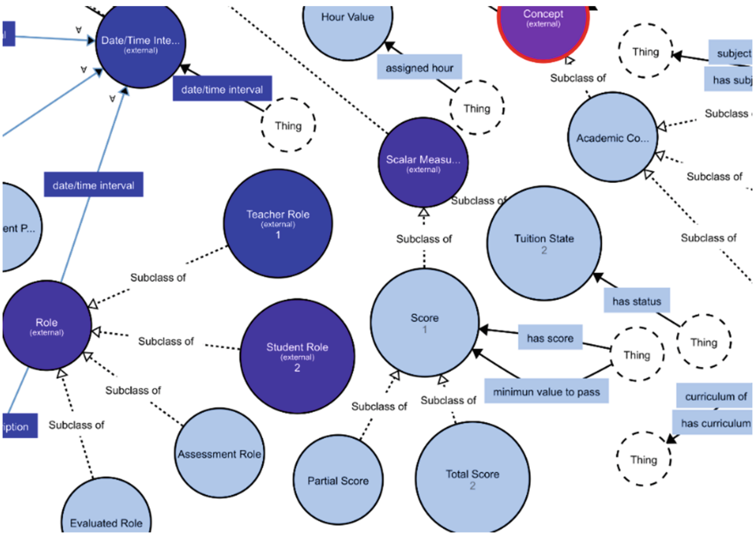

Fig. 4. VOWL's capture of the ontology OAE.

3.3 Definition of Rules

The ontology presents certain axioms that can generate knowledge on certain situations that they were presenting later, in which by means of Semantic Web Bum Language (SWRL) [17] there developed rules that by means of the definition of a precedent (body) a result implies in consistent (head-board).

```
Rule 1:
    Subject(?s) ^ 'has template activity' (?s, ?a) ^
    'Activity Template'(?a) ^ 'assigned hour'(?a, ?h) ^
    'Hour Value'(?h) -> 'assigned hour'(?s, ?h)
Rule 2:
    Curriculum(?c) ^ 'has subject'(?c, ?s) ^ Sub-
    ject(?s) ^ 'assigned hour'(?s, ?h) ^ 'Hour Val-
    ue'(?h) -> 'assigned hour'(?c, ?h)
```

Since it is possible to observe in the rule 1 and 2 the values of the hours that are assigned from the staff of activities are transferred so much to the matters and in turn the hours of the matters like it can observe in the rule 2 they are transferred to the curriculum. In the Fig. 5 1 can observe the inferences from the rule, appreciates like instance h1 and h2 corresponding to the class Hour Value that are assigned to the instances at1 and at2 respectively, they are linked by the instance s1 of the class *Subject*, Due to the fact that at1 and at2 of the class *Activity Template* they are linked with s1 by the relation 'has template activity'.

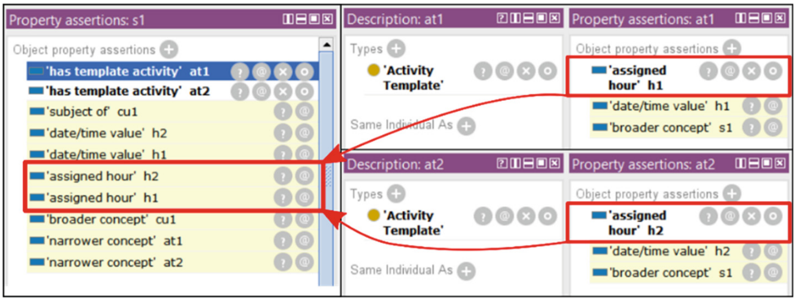

Fig. 5. SWRL inference in Protégé of rule 1.

As in the previous case we can see in the Fig. 6 that due to the fact that s1 and s2 of the class Subject they link themselves to cu1 by means of the relation 'has subject ', where cu1 is an instance of the Curriculum class, then the hours assigned to s1 and s2 are linked to the instance cu1.

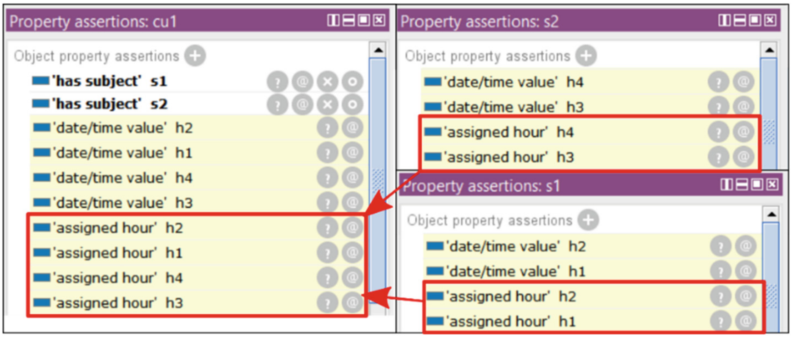

Fig. 6. SWRL inference in Protégé of rule 2.

```
Rule 3:
    Tuition(?t) ^ 'has score'(?t, ?s) ^ score(?s, ?vs)
    ^ 'tuition of'(?t, ?c) ^ vi-vo:hasSubjectArea(?c,
    ?su) ^ 'minimum value to pass'(?su, ?ss) ^
    score(?ss, ?vm) ^ swrlb:greaterThanOrEqual(?vs,
    ?vm) -> 'has status'(?t, ac:approved_subject)
Rule 4:
    Tuition(?t) ^ 'has score'(?t, ?s) ^ score(?s, ?vs)
    ^ 'tuition of'(?t, ?c) ^ vi-vo:hasSubjectArea(?c,
    ?su) ^ 'minimum value to pass'(?su, ?ss) ^
    score(?ss, ?vm) ^ swrlb:lessThan (?vs, ?vm) -> 'has
    status'(?t, ac:failed_subject)
```

The rule 3 and 4 help inference if the total grade of the tuition meets with the minimum value of the value that offers the course, this way we can know if the tuition is approved or failed. As presented in Fig. 7, the instances t1 and t2 of the class Tuition have final scores represented with the instance tsc1 and tsc2 respectively, of which tsc1 has a score of 71 and tsc2 has a score of 65, on the other hand, the instance msc of the class Score has a value of 70 that represents the minimum score of the subject which belongs the course registered in the two tuitions represented by co1 and co2. When tsc 1 has a score greater than msc, then rule 3 acts, therefore, the 'approved_subject' instance is related through the relation 'has status' as it can be seen framed in a red box in Fig. 7. On the other hand, if tsc 2 has a score lower than msc then rule 4 acts, therefore, the instance 'failed_subject' is related through the relation 'has status' as it can be seen framed in a red box in the Fig. 7.

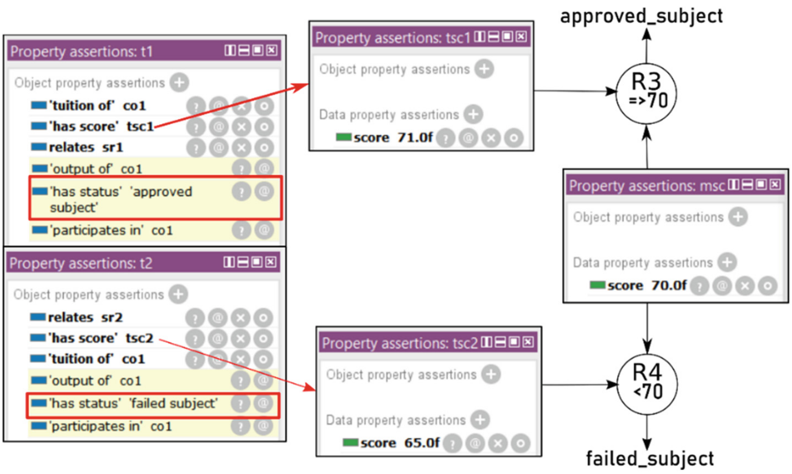

Fig. 7. SWRL inference in Protége of rules 3 and 4

4 Results

To demonstrate that the ontology fulfills the expected traceability of the conceptualization of the academic ecosystem, we have proposed a scenario in which all the modeled conditions of the exercise of a curriculum subject are met, resulting in an inference from a SQWRL query that responds to SWRL rules by ensuring that Open World Assumption (OWA) is met. The ontological network importing both the VIVO ontology and the ontology of OAE in a single project of Protégé that will be the scenario of simulation where the respective instances to the scenario will be created. The scenario of modeled instances starting from the macro curricular part, part of the systems engineering career that offers a curricular program that is comprised of two subjects (artificial intelligence and advanced calculus), with a minimum grade to pass of 70 points, where each subject consists of two templates of activities each. These activity templates have their component of hours per activity. The first result to verify the curricular traceability of a career was made with the following SQWRL query:

```
ac:Career(?ca) ^ ac:label(?ca,?lca) ^ ac:'has curricu-
lum' (?ca,?cu) ^ ac:'has sub-ject'(?cu,?su) ^
ac:label(?su,?lsu) ^ ac:'has activity tem-
plate'(?su,?ta) ^ ac:label(?ta,?lta) ^ ac:'assigned
hour'(?ta,?h) ^ ac:hour(?h,?lh) ->
sqwrl:select(?lca,?lsu,?lta,?lh)
```

As can be seen in Table 3, the result of the previous consultation gives us the subjects of a curricular program that offers a set of subjects with their respective components of activities and hours dedicated to the activity.

Table 3. SQWRL result of the curricular composition

Career (lca)	Subject (lsu)	Activity (lta)	Hours (lh)
Computer Science	"Higher Math"	"Homework"	"8.0"^^xsd:float
Computer Science	"Higher Math"	"Test"	"4.0"^^xsd:float
Computer Science	"Artificial Intelligence"	"Test"	"4.0"^^xsd:float
Computer Science	"Artificial Intelligence"	"Test"	"4.0"^^xsd:float

In the second part, the operation between VIVO and OAE is checked, taking as reference the scenario of: two students and a teacher who are in the same course of the subject of artificial intelligence, in which the first student has a grade that satisfies the minimum condition of the subject and the second student doesn't. In this case, the personal information of each person uses the VIVO mode [18] and the academic information of the OAE model. For this verification, the following query was used:

```
foaf:Person(?p) ^ obo:ARG_2000028(?p, ?vi) ^
vcard:hasName(?vi, ?vn) ^ vcard:familyName(?vn, ?lfn) ^
vcard:givenName(?vn, ?lgn) ^ obo:RO_0000053(?p, ?r) ^
ac:RAC0000012(?r, ?t) ^ ac:RAC0000014(?t, ?sc) ^
ac:AC0000025(?sc) ^ ac:score(?sc, ?lsc) ^
ac:RAC0000015(?t, ?st) ^ ac:label(?st, ?lst) ^
obo:BFO_0000055(?co, ?r) ^ vivo:hasSubjectArea(?co,
?su) ^ ac:RAC0000008(?su, ?ms) ^ ac:score(?ms, ?lms) ^
ac:label(?su, ?lsu) -> sqwrl:select(?lfn, ?lgn, ?lsu,
?lms, ?lsc, ?lst)
```

As shown in Table 4, we can see the result of the previous query and how the rules defined above interact with the rest of the ontology and its instances, providing us with a summary of the Higher Math course.

Table 4. SQWRL result of the academic process.

First name (lfn)	Last name (lgn)	Subject (lsu)	Minimum score (lms)	Score (lsc)	Tuition state (lst)
Turner	Alex	Higher Math	"70.0"^^xsd: float	"71.0"^^xsd: float	Approved subject
Parra	Alexandra	Higher Math	"70.0"^^xsd: float	"65.0"^^xsd: float	Failed subject

5 Conclusions

We have presented a formal model that represents the academic ecosystem from a macro curricular perspective, starting from this point it can be seen how these analytical programs are combined with the chair process between the involved actors both students and teachers, these processes generate outputs in the form of grades from activities that are indicators of achievements that are recorded in the student's enrollment, these achievements allow knowing the suitability of the student in their learning process by reason of a minimum measure of the subject. The definition of rules using SWRL was a very important instrument for the generation of new knowledge, in the rule definition phase we could see how the tuition of a student automatically changed state according to the result of his final grade, this [7] thanks to the model of the subjects that already define a minimum grade standard for the approval of the academic process of an offered course. It was observed that the coexistence between two ontologies in an ontological network comprised by VIVO and OAE was successful in developing our ontology based on a high-level ontology such as BFO, the integration of the links for the alignment of the ontological network was very convenient and it can be seen in the definition of rules and in the results part.

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Challenges for Logistics Education in Industry 4.0

Magdalena Wrobel-Lachowska[1], Aleksandra Polak-Sopinska[2](✉), and Zbigniew Wisniewski[1]

[1] Faculty of Management and Production Engineering, Lodz University of Technology, Wolczanska 215, 90-924 Lodz, Poland
{magdalena.wrobel-lachowska, aleksandra.polak-sopinska,harvester}@p.lodz.pl
[2] Department of Production Management and Logistics, Faculty of Management and Production Engineering, Lodz University of Technology, Wolczanska 215, 90-924 Lodz, Poland

Abstract. Logistics 4.0, as well as Industry 4.0 is setting high demands on the education process, as logistics will need highly skilled workers. Not only specialists, but also operational workers will soon perform mainly organizational and conceptual tasks. This causes the necessity of adapting educational process to a new situation. The objective of this paper is to present the analysis of the challenges for logistic education. In research, the selected logistic companies and universities in the Lodz Region in Poland were investigated. There were conducted: Individual In-depth Interview with companies and universities representatives, survey with employed on logistics work positions and analyses of logistics study programs. The research was conducted in the Lodz Region, which is predestined for the development of logistics, because of its central location and developing road infrastructure. The paper presents the results of an analysis of the requirements for education in Logistics 4.0.

Keywords: Logistics 4.0 · Education · Lifelong learning · Learning outcomes Logistician

1 Introduction

One of the inherent characteristics of the modern society is a continuous change that is visible in social, economic and technical aspects of life. Those aspects intersect, implying the transformations in a number of areas, including the area of education. Digital revolution, global economy and social changes had made high demands for employees and their competences. The currently ongoing *4th Industrial Revolution* called *Industry 4.0* [1], is setting new standards of life and work, which as a result, cause new requirements for education. That cause new challenges [2]. Universities need to cooperate with companies in shaping competences [3].

In Industry 4.0, having the proper competences is crucial also for specialist profession, such as logistician. Logistician is a specialist in logistics, the person who is planning,

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organizing, driving and controlling processes of streams flow in the enterprise or throughout the supply chain. Logistician manages the processes of flows: things – that is, raw materials, materials, semi-finished products, finished products, non-conforming products, industrial waste, post-consumer waste, services – that is, actions taken in order to meet the specific needs, financial resources, information and people. Management of logistic flow occurs in all phases of the logistics process: in the phase of the supply, production, distribution and disposal. In order to efficiently perform their tasks, logistics workers must have appropriate competences that should be developed in education process.

In *Logistics 4.0* – being a part of Industry 4.0, the increasing role of ICT-assisted mental processes, and decreasing the role of physical work (which are increasingly cheaper and easier to automate), generates the need to define the new requirements for employees.

2 The Concept of Industry 4.0

The idea of Industry 4.0 emerged in 2011 during Hannover Fairs and crystalized in 2013. The term represents the 4th industrial revolution [4] in which the main role plays the *cyber-physical systems* (CPS). CPS are considered as connecting and coordination between computational and physical resources [5]. It should be understood that computer-based algorithms control and manage many aspects of contemporary industry. CPS gave the possibilities of functioning of smart solutions in factories or warehouses.

The most important components of Industry 4.0, apart from cyber-physical systems, are [6]:

- *Internet of Things (IoT)* – a network of physical devices and applications connected and exchanging information in real time;
- *the cloud computing* – IT technology enabling ubiquitous access to system resources and data processing via Internet;
- *the edge computing* – method of optimizing cloud computing systems, where the data is processed on the edge of the network, as close to the source as possible;
- *Big Data analytics* – processing large and varied data sets;
- *autonomous production* or autonomous assembly – self organizing computer assisted production planning;
- *the IT/OT convergence* – increase of the role of IT solutions in the operational area;
- *additive manufacturing* – 3D printing and fast prototyping;
- advanced robots and *co-robots* (cobots) – collaborative robots physically interacting with workers in production areas;
- *augmented reality* – system connecting a physical, real-world environment with computer-generated ones;
- *horizontal and vertical integration* – a kind of business expansion strategy;
- rapid application development – allowing to support various aspects of human activities;
- *digital twin* simulation models – technology based on digital model of machines or production systems that allows for real-time monitoring and designing new business.

Presented aspects can be divided into four main areas for the implementation of Industry 4.0: Information and Communication Technologies (ICT), robotics, sensor and innovative production systems that are connected by logistics. Logistics join Europe's Manufacturing Networks and give opportunity for further development [7].

Logistics 4.0 being a part of Industry 4.0 consist of the same elements and assumptions. On the one hand, assumptions of Industry 4.0 gave new possibilities for logistics industry development, but on the other hand, it also set new demands regarding logistics organizations and their employees. IoT, co-bots, autonomous production and assembly, augmented reality may minimize the role of operational workers. The cloud computing, Big Data analytics and digital twin can set high expectations form specialist. That is why revolution in roles in the logistics systems is being predicted [8].

The human factor may become more and more important aspect of work [9], but also there may be no need to use human force for performing simple tasks.

3 Requirements for Logistics Education – Research Findings

In research, which were conducted in years 2014–2016, the selected logistic companies and universities in the Lodz Region in Poland were investigated. There were conducted: Individual In-depth Interview with companies and universities representatives, survey with employed on logistics work positions and analyses of logistics study programs. Survey was conducted with 166 employees working in 38 companies operating in logistics industry or in which logistics processes are crucial. The study involved people employed at one of three levels of the position:

– operational employees (e.g. office workers, logistics operators, warehouses, etc.);
– specialists, coordinators (e.g. logistics specialists, team leaders, etc.);
– managers (e.g. department managers, directors).

In the paper, only findings for specialists in logistics are presented.

Information obtained in survey were particularized during the individual in-depth interviews (IDI), conduced with operational managers and strategic managers responsible for the area of logistics in the enterprise, with employees of the Human Resource departments responsible for cooperation with universities and with representatives of universities and logistics high schools profile responsible for cooperation with business.

Due to development of logistics industry, both in the Lodz Region and in whole Poland, the demand for competent logistics staff is growing, what affect interest in the field of studies offering education in the area of logistics. That is why also all programs of logistics studies offered by universities and colleges in Lodz Region were analyzed.

The research was conducted in the Lodz Region, which is predestined for the development of logistics, because of its central location and developing road infrastructure. Modern and complete road infrastructure significantly affect the quality of transport and its' planning, but also determines the location of warehouse, distribution and logistics centers.

3.1 Learning Methods in Shaping Competences

Logistics employees participating in the survey were asked about basic competences and attitudes needed in their job position. The most important competences indicated for logistics specialist are presented in Table 1.

Table 1. The most important competences for logistics specialist

Competence	Definitely important	Rather important
Analytical competence	77.8%	13.3%
Communication skills	73.9%	15.2%
Planning skills	69.6%	21.7%
Ability to work under time pressure	68.9%	22.2%
Organizing skills	67.4%	26.1%
Ability to self-organizing	66.7%	22.2%
Teamwork skills	64.4%	31.1%
Efficiency	63.0%	26.1%
Responsibility	63.0%	27.1%
Involvement	60.9%	23.9%

Presented competences need to be developed during academy education and measured by learning outcomes.

In the process of logistics education, there is a need to develop competences associated with the skills and abilities, since they are necessary to achieve success in particular tasks. Such competences include:

– interpersonal communication,
– leadership,
– organizational competences.

Very important are also the competences associated with the action styles, that is:

– planning and organizing skills,
– prediction and long-term thinking,
– act in an orderly and precise way (ability to self-organizing),
– ability to work under time pressure.

The role of the learning process is also strengthening competences related to ability, which are related to the potential of individuals, as well as its development opportunities and the skills to use the abilities to acquire new competence, that is, the key competences from the self-improvement and professional development point of view.

All those competences should be developed during education process but also can be extended via continuous learning in the workplace. Conducting university projects but also company ones allows to developed those skills. Also *mentoring* can be a solution, as students will be able to gain more independence in the learning process. Mentoring ca be used both in universitie and companies.

As is comes from the IDI research, logistics industry needs employees who can use the vast amount of available information and data. It is due to the fact that with the development of information and communication technologies (ICT) logistics is becoming more and more addicted from them. There is a need for employees who are experts in the use of ICT tools and who are efficient users of ICT solutions. This implies a need to develop learning ICT competence, which is another key logistical competence.

ICT competence should be developed throughout the whole education process from the beginning of elementary school.

Creative and innovative approach to solving problems is another competences pointed in the study. Interesting is fact that both of them were considered as definitely important only by 43,2% and 36,3% of respondents and as rather important by 43,8% and 34,6% of respondents. During interviews, respondents asked why creative and innovative approach were not pointed as the most important ones, indicated that on the one hand, those competences are needed for solving problems but on the other hand, they are not necessary for routine tasks which logistics specialist perform every day.

However, for Logistics 4.0 it is needed to have logisticians who can solve problems in out-of-the-box way. The development of this competence is possible thanks to the activating forms of training, such *as design thinking* or *problem-based learning*. All those methods increase the role and independence of the student in the learning process. Changing teaching methods into learning methods is one of the biggest challenges for education.

Group projects are also the best way to improve teamwork skills, which are necessary in logistics. Moreover, while doing project student can practice *peer-to-peer learning*, which means to learn together and learn from each other. The role of teacher is more being a facilitator (who is motivating and inspiring students) than a master. Peer-to-peer learning is also similar to the situation, which is in companies: workers learn from each other.

Both survey and IDI have shown that the theoretical knowledge is not the key competence of logistics graduates. It should be acquired not only in the formal education process, but also during work and additional training resulting from the emerging professional challenge. Knowledge of logistician beginning work should be general and broad, in order to give it a quick review. In education, the learner should assimilate knowledge, based on solving the greatest number of *case studies* based on real life situations and executing application projects. As it was indicated in studies, the logistics industry requires from a graduate entering the job market to know its specifics requirements and limitations.

Problem methods, such as case studies or projects carried out in enterprises, positively evaluated by employers, allow student to better understand the problems, than in the case of delivering methods. Routine exercises that require simple calculations, do not develop the competence of critical thinking and creative thinking so, as case studies or problem-based learning. It is very important, as one of the key competences of logisticians, which was pointed out in the study, is the ability to critical thinking. Critical thinking consist of analytical competence, understand as ability to analyze, evaluate, interpret and infer information, as well as competence to synthesize information, understand as ability to combine parts or elements and making decisions based on them [10]. That is why one of the most important requirement for education in Logistics 4.0 is to change the learning and teaching methods into more active ones.

As is apparent from the needs of the industry, logistics education should be implemented as an *interdisciplinary program* (combining economic and technical sciences). Graduates of logistics studies should be trained primarily to professional work, and to a lesser extent to typical academic scientific work. In accordance with the idea of specialization, research and development unit should carry out the creation of new solutions, including solutions for logistics. This does not mean that graduates of logistics studies should be deprived of the chance to work as an engineer, but their dominant role is being proactive user – fast learner specialist who can creatively and procedurally use technology at work every day. This is what labor market demands from logistics expects. Of course, there are differences in the structure of needed competences in companies of different sizes, but they are not significant.

Another learning methods which will gain on popularity are webinars and e-learning. Both of them allow to share knowledge without necessity of being in the same place, or even in the same time, together. What is more, they allows to share knowledge globally. Proper use of webinars and e-learning can be challenging not only for companies, but also for universities and its employees.

3.2 Cooperation with Companies in Shaping Competences

Respondents highlighted the necessity for increasing the role of the *internships* for students. That can allow for better shaping personal competences, such as the ability to make decisions, work organization, problem-solving, coping with stress and with ambiguity or self-reliance. Participation in the internship force the need for cooperation with the staff of the various departments and levels of management, so that the student acquires social competence, such as the ability to build relationships with others, collaboration with other or communication skills. Alternative to traditional internship can be *dual studies*.

Achieving by students learning outcomes corresponding to the competences needed in work is possible for instance thanks to the participation of the representatives of companies in the process of education. With a minimum of three months continuous internships logistics students will be able to acquire the necessary professional skills. It will also be an opportunity for employers to choose the best apprentices and their employment, at a much lower cost. A dual system being an alternative for the practical profile of studies is also the perfect solution for logistics education, as it is shown by examples of many German universities pursuing these forms of learning. Schools and colleges should not have difficulty in finding the right business partners; take into account the multitude of companies in the logistics industry. Especially because that cooperation in this area has already begun, and numerous companies postulated willingness to deepen or widen it.

The study showed that from the point of view of enterprises cooperation between universities and companies in the area of shaping competence of graduates of logistics is neither accurate nor consistent, and its scope is still very narrow. A significant part of the forms of activities cannot be called cooperation, since it has no characteristics of system, and has rather the character of casual contacts. Companies carry out projects with universities or directly with students, however, do not see tangible benefits of cooperation. What's more, companies have many concerns as to the competence of the students, their theoretical and practical preparation, as well as involvement in tasks and independence. Although companies were not fully satisfied with the cooperation with universities, they wanted to continue the current cooperation and to develop it.

The openness of the companies and universities on cooperation in the field of forming competence of students and graduates is optimistic. Both sides were eager to improve the relationship between universities and business. In the study, respondents declared a will to strengthen cooperation, inter alia by *co-leading* the classes at universities and technical assistance from specialists in the *development of training programs*. Universities and companies, as well as local authorities, realize that in order to increase the competitiveness of the region is essential that cooperation between the business and universities will be strengthened. This will allow for such knowledge management in the process of education that will enable students to achieve learning outcomes that correspond to the key logistics competence.

Approach to the learning process of the logistics, taking into account the mentioned guidelines should allow to provide the highest skills and knowledge graduates of high schools and colleges.

4 Summary

Changes taking place in modern society force a new look at the issue of education, both in the context of educational needs, education process and learning outcomes. Knowledge and processes associated with it are considerate in different way than in previous years.

Appropriate human resources are necessary for development of the logistics industry. The concept of Logistics 4.0, as well as the directions of its development, affect the competences' requirements, which influence the needs for the learning process. This is a challenge for education units, such as universities, but also high schools, which need to adjust education programs, in particular the learning outcomes, to the needs of the industry.

To increase the professional attractiveness of students and graduates, in the process of logistics education universities should resign from the traditional learning methods and use the methods that activates students, forcing them to analyze the problem and search for solutions based on the available information (as it will take place in their future professional work). To make the logistics education suit global trends and requirements, universities can change the role of the teacher from the master giving the solution, to the role of mentor, who oversees the search for answers. This will allow the students to gain research independence, which will in the future result during the implementation of future projects.

To achieve high quality of logistics education, cooperation between universities and companies needs to be reinforced. Both universities, companies and local authorities need to participate in shaping competences needed on the market. The relationship must be accurate and consistent and must adopt a structured form. Universities should also strengthen innovation and knowledge transfer, so that the solutions generated at universities may flow into the business and the business more often and are more likely may report the need for cooperation.

Moreover, in study programs for logistics studies there should be implemented aspects of human factor, as success of Logistics 4.0 companies will depend not only on technology but mainly on competent employees owning proper competences.

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Education in Medicine, Safety and Rehabilitation

Specialized Training in 3D Printing and Practical Use of Acquired Knowledge – 3DSPEC Online Course

Dariusz Michalak[1(✉)], Magdalena Rozmus[1(✉)], Juan Gomez[2], Miran Papež[3(✉)], Viljem Osojnik[3(✉)], Diana R. Bueno[4(✉)], Grzegorz Świerczek[5(✉)], and Ewelina Limanowska[5(✉)]

[1] KOMAG Institute of Mining Technology, Gliwice, Poland
{dmichalak,mrozmus}@komag.eu
[2] Biomechanics Institute of Valencia (IBV), Universitat Politècnica de València, Camino de Vera s/n, Edificio 9C, 46022 Valencia, Spain
juan.gomez@ibv.upv.es
[3] Šolski center Velenje, Velenje, Slovenia
{miran.papez,viljem.osojnik}@scv.si
[4] Exovite Laboratorio I+D, Saragossa, Spain
diana@exovite.com
[5] County Vocational Education Centre, Wodzisław Śląski, Poland
swierczek.gr@gmail.com, ewelina.limanowska@gmail.com

Abstract. 3D printing technology is developing rapidly. Its application covers more and more areas due to increasing quality, functionality and affordability of 3D printers. Mastering of 3D printing becomes recommended and expected in growing number of professions. This article presents innovative approach to development and providing of knowledge resources for end-users from education, healthcare, design and SMEs sector who wish to use 3D printing in their professional practice.

Keywords: 3D printing · Online course · E-learning course · 3DSPEC

1 Introduction

Nowadays 3D printing technology is used mainly in medicine (implants, orthoses, etc.), industry (e.g. manufacture of the components in short series), and moreover - this technology is increasingly applied in education: in vocational schools and universities (mainly in areas related to medicine and art as well as technique and technology) [1–4]. Although 3D printing issues are included in training curricula in organizations that provide vocational training, courses that give comprehensive (i.e. including theory and practice) training in 3D printing and are addressed to specific professions or refer to specific tasks conducted at work are not commonly available [5]. Moreover, such courses on 3D printing are not freely available on-line, which is a serious barrier for acquiring or enhancement of knowledge and skills necessary for particular professional

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applications. This situation was the reason for undertaking 3DSPEC project (funded within Erasmus+ programme), the aim of which is development of a course that provides professionally-related competencies in 3D printing. The course is hereinafter called 3DSPEC course.

During development of concept of the 3DSPEC course, online access to the training materials was accepted as crucial. Therefore, an Internet platform with training materials will be used to provide knowledge. To develop competencies in using a given technology not only theoretical knowledge but also skills are necessary. For that reason, easy and convenient access to training materials is not sufficient - practical use of obtained knowledge in practice must be also included in the course. To meet this requirement, a 3D Printing Centre will be developed. It is an Internet platform which gives access to 3D printers with which the 3DSPEC course trainees will do experimental 3D printing of their own projects.

Another important condition is relevance of provided content for trainees representing particular professions. There is subject knowledge, in particular declarative knowledge providing theoretical fundamentals, which should be absorbed by all trainees. The same training materials will be used by all trainees to obtain this knowledge. There is also procedural knowledge showing how to carry out activities related directly to 3D printing process [6, 7]. Training materials providing this knowledge should be properly developed and selected to match needs, abilities but also possible interests of trainees representing a given profession. Moreover, this type of knowledge is often tacit [8], hence a process of creating training materials should be based inter aila on recording human experiences with the use of charts, schemas, videos etc.

The following part of the article presents methodology used to develop the 3DSPEC course which meets requirements indicated above.

2 Materials and Methods

Methodology used for development of the 3DSPEC course is presented in the Fig. 1.

The 3DSPEC course to be developed is expected: (i) to provide theoretical content regarding 3D printing technology, (ii) to present examples of use of 3D printing in particular professional activities, (iii) to give opportunity of practical use of the technology. The content is planned to be available in four language versions.

The course is addressed to end-users whose professional activity is related with education, healthcare, design and SMEs. Therefore, there are 4 target groups of the course, particular needs of which should be taken into account.

To develop a training platform with content that meets future users' actual needs, a proper curriculum is necessary. These needs must be identified by research. Information obtained serves as basis for the curriculum development. In the 3DSPEC project the research was done by survey and interviews with representatives of all target groups involved.

All elements indicated above: training platform content, curriculum and end-users' needs are related and must be consistent (what is shown in the Fig. 1).

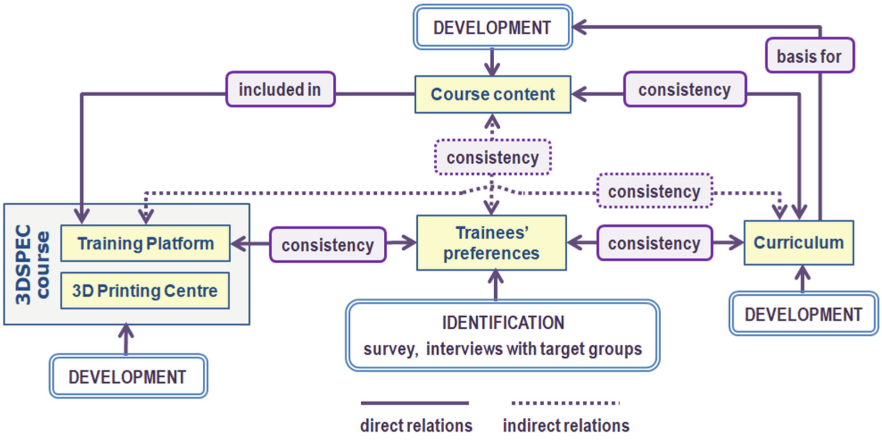

Fig. 1. Methodology used for development of the 3DSPEC course

2.1 Identification of Training Preferences

To identify future trainees' needs regarding 3D printing, data collected via survey and focus groups/interviews were analyzed. Both survey and interviews were based on the same questionnaire to keep consistency of obtained data, which contributes to effective data analysis and drawing useful conclusions. It was agreed that there will be not only electronic but also traditional (paper) questionnaires used to reach wider group of respondents. MS Word was used for the printable version and LimeSurvey system for the electronic version. In particular the following activities were carried out:

1. development of a questionnaire (in all planned languages) – establishment of its content: introduction information, questions, etc.
2. development of final language versions of paper and electronic questionnaires:
   (a) adjustment of files with questionnaires for printing
   (b) implementation of the questionnaire within the system for electronic surveys
   (c) gathering data with use of the questionnaires – carrying out of: electronic survey, paper-based survey, focus groups/interviews,
3. data analysis and drawing of conclusions.

There was one questionnaire including questions for all target groups. It was assumed that answering for some questions would be expected depending on target group or groups indicated by a respondent. In the electronic survey questions were visible depending on target group(s) declared by a respondent.

The first version of questionnaire was in English to enable its development by the whole multinational project consortium. Draft version was developed by the project coordinator (.docx file), sent (via email) to the project partners and then modified based on the feedback. This cycle was repeated until the final version was developed. Next it was translated by the project partners to their native language. The project coordinator transformed all files with questionnaires (all language versions) into: (i) paper questionnaires ready for distribution, (ii) electronic questionnaires accessible for respondents. Files with the printable questionnaires and links to the electronic questionnaires were sent to the project partners.

It was agreed that all questionnaires used in the research should be visually consistent. Files with language versions of paper questionnaire were identically edited (fonts, interlines, margins, size of gaps for answers etc.) by the project coordinator and provided to the project partners. For electronic questionnaires a template (consistent with paper version) was developed in the LimeSurvey system by the project coordinator.

Both paper and electronic questionnaires were verified before distribution (e.g. if any spelling errors should be corrected). This way shortcomings that could lower quality of the questionnaires have been avoided. Information about questionnaires ready for distribution was clearly announced to the partners.

To conduct the electronic survey, informative e-mails were sent to potential respondents to encourage them to take part in the research. They included overall information about the 3DSPEC project and objectives of the survey as well as links to the questionnaires. Paper surveys were provided directly to potential respondents or relevant files to be printed were provided to them along with the informative e-mails. Data from all filled in paper questionnaires were then entered into the LimeSurvey system for analysis purposes.

Paper questionnaires were also used during focus groups/interviews carried at the interviewed participants' premises or at a project partners' site. Acquired information was written down by an interviewer.

Statistical processing of data gathered in the LimeSurvey system was done by means of: (i) statistical module of the system, (ii) MS EXCEL - data exported from the LimeSurvey were used to obtain additional information useful for proper curriculum development. Results of the research - statistical processing of obtained answers and drawn conclusions were presented in a report, separately for each target group.

In the questionnaire there were proposed general topics – for all target groups and specialist topics for a particular target group. Based on the research it was identified what topics should be included in the course and how important they are for each target group. Sample chart produced in MS EXCEL based on answers provided by respondents who declared target group 'designers' in shown in the Fig. 2.

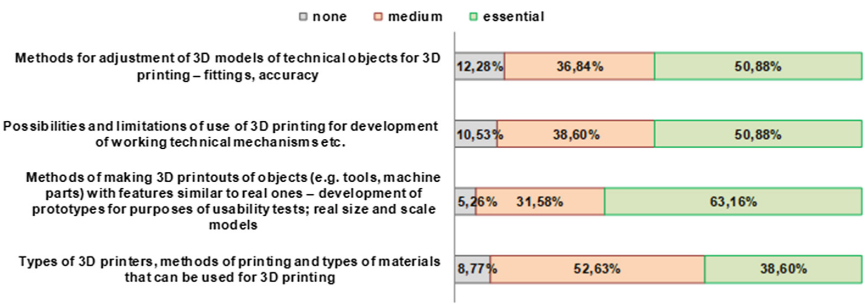

Fig. 2. Specialist topics expected in the course and their importance for designers

2.2 Course Curriculum Development

The curriculum was developed in an iterative way and all project partners were involved, which enables the best usage of available human potential (Fig. 3). The first version was developed by the project coordinator and sent to the project partners for feedback. The curriculum was modified as necessary and again sent to the partners for feedback, which was done until the final version was agreed.

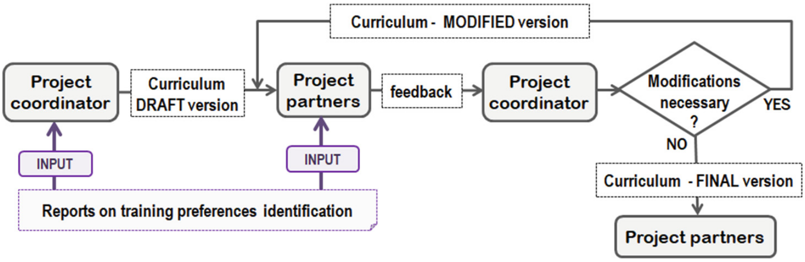

Fig. 3. The curriculum development process

During development of the curriculum, requirements regarding access to training materials and a concept regarding structure of the course were established. The curriculum should provide information that enables to assign each training material to relevant course target group(s). In the course the trainees will indicate area or areas of professional activity for which they wish to acquire knowledge and skills in 3D printing. There will be four options: education, health care, design, SMEs. Training materials will become accessible for a trainee depending on the selected option(s).

The 3DSPEC course will consist of (Fig. 4): (i) modules - they will be the main units in the course, (ii) final exam. Each module will include the following parts:

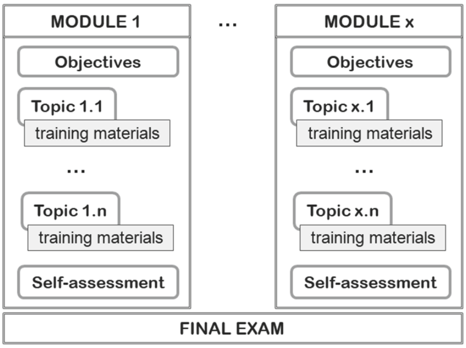

Fig. 4. Structure of the 3DSPEC course

– objectives – a short description regarding knowledge and/or skills to be acquired by a trainee who has completed the module,
– topics – to each topic there will be training materials linked,

– self-assessment – a task, e.g. a test that enables a trainee to assess how well they assimilated knowledge/skills.

To properly meet needs and interests of a trainee there will be two types of topics in the course. General topics will be available and obligatory for all trainees regardless area of professional activity declared by them. Profiled topics will include content obligatory for one target group and optional (because might be of interest) for other target group(s).

Each type of topic will have individual structure. General topics will include theory and downloadable materials. Profiled topics will include: (i) example, the aim of which is to demonstrate how 3D printing can be used in particular professional activities, (ii) related theory - when necessary. All examples will have the same structure to make them consistent (Fig. 5). They are relevantly entitled. To give a trainee some introductory information regarding a given example, first a short description is shown. Also final result to be achieved is presented in a graphical way, in the 'final object' section. Next a procedure to be followed is presented in a step-by-step format. To facilitate hands-on carrying out of the procedure, all necessary additional materials should be provided to a trainee – they are included in the 'downloadable materials' section. These materials are e.g. stl files, 3D models, source files for a 3D printer, photos.

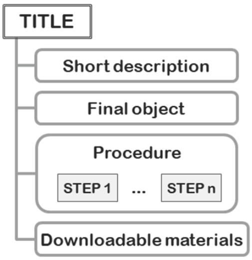

Fig. 5. Structure of an example in a profiled topic

To correctly understand examples and exercise them, some additional knowledge (not included in general topics) might be necessary. In such case relevant theory will be added/included in a given profiled topic.

All topics proposed in the questionnaires used for identification of the future trainees' expectations became a basis for definition of modules and topics of the course. They were selected by a group of respondents that is big enough to find these topics worth including in the course.

The course will be run on an Internet platform dedicated for training (Moodle). Access to the platform will be given to a trainee after registration based on which login and password will be assigned to them. During the registration a trainee's area(s) of professional activity (target group) will be identified. It is very important because based on this declaration proper training materials to be presented to a given trainee will be selected. As it was mentioned, there will be general topics - obligatory for each trainee regardless area of target group declared by them, and profiled topics - obligatory only for trainees who declared a given target group. Depending on the content provided, profiled topics will be available for trainees, who wish to browse them but didn't declare a target group to which a given topic is assigned. Therefore, each profiled topic might be obligatory, optional or not available for trainees from particular target groups. All these situations should be included in the 3DSPEC course curriculum.

Structure of the curriculum for the 3DSPEC course is presented in the Fig. 6. Accessibility of topics for target groups is marked as follows:

– mark 'X' - topic obligatory for a given target group
– mark 'O' - topic optional for a given target group (their content will not be included in the final exam)
– mark '-' - topic not accessible for a given target group (due to its specialized content).

Contents	Target group				
	Education	Design	Healthcare	SMEs	3D Printer Assembly & Development
Module 1. Introduction: General view of the 3D printing technology	X	X	X	X	X
1.1. How the additive technologies work	X	X	X	X	X
1.1.1. 3D printers – overall information about structure and principle of operation.	X	X	X	X	X
1.1.2. 3D printers – properties and usability	X	X	X	X	X
1.1.3. 3D printers – relation between properties and possible applications	X	X	X	X	X
1.2. Possibilities and limitations of application - Main advantages and disadvantages	X	X	X	X	X
1.3. State of the art of the additive technology - available solutions, other methods	X	X	X	X	X
Module 2. Preparing of input file for 3D printer	X	X	X	X	X
2.1. Introduction to 3D modelling	X	X	X	X	X
2.2. Review of software for 3D modelling	X	X	X	X	X
2.6. Free repositories of 3D m... 3D printing	X	X	X		X
2.7. Work in slicer software - transforming of 3D model for a 3D printer	X	X	X	X	X
Module 3. Materials used in 3D printing	X	X	X	X	X
3.1. Description of the most often used materials.	X	X	X	X	X
3.2. Mechanical properties of 3D printed objects	X	X	X	X	X
Module 4. Examples of use of 3D printing in activities conducted in your profession	X	X	X	X	O
4.1. Additive 3D printing applications in the healtcare area	O	O	X	O	-
4.1.1. 3D printouts for informing a patient about their disease, pathological changes of organs, therapy/surgery	-	O	X	O	-
4.1.2. 3D printouts for preparing a patient for surgery	-	-	X	O	-
4.4.1. Methods for adjustment of 3D ... of technical objects for 3D printing	O	X	O	O	
4.4.2. Fast prototyping for design assessment	O	X	O	O	O
Module 5. Self designing and assembling of 3D printers	O	O	O	O	X
5.1. 3D printers – properties and usability	O	O	O	O	X
5.2. Design of 3D printer - case study 1	O	O	O	O	X
5.3. Design of 3D printer - case study 2	O	O	O	O	X
5.4. Assembly 3D printer - case study	O	O	O	O	X

Fig. 6. Structure of the 3DSPEC course curriculum

Apart from the target groups there is also another group of course users included in the curriculum – trainees who wish to acquire knowledge and skills necessary for building 3D printers on one's own. In the Fig. 6 they are represented under '3D Printer Assembly & Development' column. For these trainees general topics (in the Modules 1–3) and topics related to design and assembly of 3D printers (in the Module 5) will be obligatory.

Topics providing knowledge about design and assembly of 3D printers will be available for all target groups - to give the trainees opportunity to acquire ability to build a

3D printer. The research carried out to identify needs of potential course users revealed that in all target groups knowledge about practical issues regarding 3D printing is low. Therefore, it is justified to assume that after acquiring basic theoretical and practical knowledge regarding preparing and making of 3D printouts, a part of trainees will become interested to gain knowledge and skills in building of 3D printers.

2.3 Training Materials Development

To each topic in the curriculum, a partner or partners responsible for development of relevant content were assigned. Therefore, each partner was assigned to a number of topics.

To make all developed training materials consistent and to make easier their conversion into the Moodle course, a template was developed to be used by all project partners. Both general and profiled topics are included in the template. The template is in a form of PowerPoint presentation, which in practice means that presentations with content of training materials are to be developed.

First, the template was prepared by the project coordinator and provided to the project partners for feedback. Modified version was sent to the partners and the process was continued until the final version was ready. It was sent to the partners and development of training materials started.

When creating a course, a curriculum developed for this course should be treated as framework/road map. Modifications might be necessary or recommended during development of the training materials content. If a group of partners participates in the process, they should discuss and agree on each modification to avoid gaps or redundancy in the training materials.

Sample slides of template and training materials content are presented in the Fig. 7.

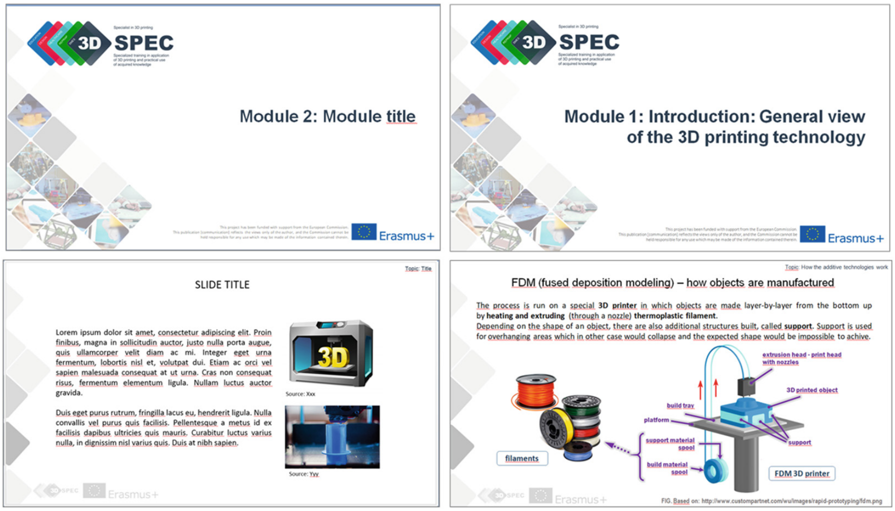

Fig. 7. The template (left) and its sample implementation (right)

To maintain high quality of the course content, involved partners should share with each other presentations being under development - for feedback. This way the synergy effect would take place. Ready PowerPoint presentations with training materials content will be transformed into the 3DSPEC course in the Moodle platform.

3 3D Printing Center

3D Printing Center is an important part of the whole 3DSPEC course 'ecosystem'. It is an Internet platform on which it is possible to order 3D printing of a given object on one of available 3D printers. Taking into account the importance of the practical application of acquired knowledge, this part of the training course is crucial and gives trainees opportunity to check, verify and correct theoretical knowledge regarding 3D printing technology. Practical implementation of acquired knowledge is one of the innovative aspects of the 3DSPEC project. Moreover, due to development of the 3D Printing Centre, persons who will be interested to assemble 3D printers on their own will be also provided with guidance on relevant good practices, if they need it. The platform will be available for persons who participated in the 3DSPEC course as well as for the project partners - for purposes of assembly of 3D printers on their own. The whole organizational activities regarding development of the 3D Printing Centre include development of necessary hardware, purchase of tools and ready-to-use 3D printers and acquiring of necessary expert knowledge that allows to support persons who are willing to build a 3D printer on their own. Connection between hardware and software components of the centre is realized indirectly via Internet network. All 3D printers in the 3D Printing Centre due to their different geographic localisation will be assigned to different group of end users. Data transfer between the Internet platform and selected 3D printers will be implemented manually, by specialists from the project partners. Manual mode of data transfer and verification of uploaded 3D models is caused by safety reasons and current limitations of slicing software (an input file for a 3D printer is generated there).

Manual verification of all 3D models sent for printing will protect infrastructure of the 3D Printing Centre against wrongly prepared printing tasks. Therefore it enables complete process control and ensures high quality of final printouts. Flow of information during the process of ordering a 3D printout is shown in the Fig. 8.

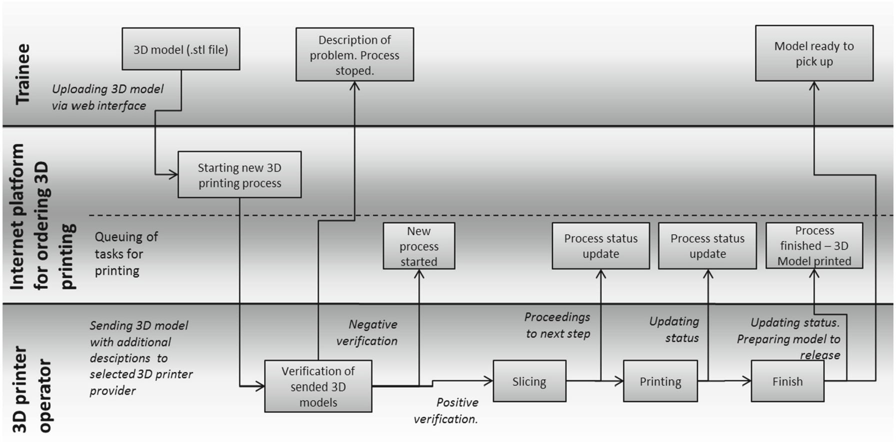

Fig. 8. Actors interaction and information flow inside the 3D Printing Centre

At the Internet platform not only ordering of 3D printing of an uploaded 3D model is possible. It also provides all necessary information and support for successful making 3D printouts. Figure 9 presents screenshot from the Internet platform managing information about current stage of 3D printing process realisation.

Fig. 9. The 3D Printing Centre Internet platform – printing process observation module

The following functionalities will be included in the solution:

– queuing of tasks for 3D printing connected with distribution of printing tasks among available printers,
– estimation of time and amount of filament necessary for printing of a given model,
– live observation of the printing process,
– access to library of 3D models send by other users and discussion groups
– access to the training materials (3DSPEC training platform) and 3D printing glossary covering all necessary information for proper understanding of presented content.

4 Conclusions

3D printing technology provides new opportunities in many areas of professional activity. Constantly increasing demand for workers who can apply this technology in their professional practice causes that proper training by which competency in use of 3D printing for particular tasks at work can be obtained is necessary. To develop such abilities, a training should provide not only relevant knowledge but also skills. Access to training materials should be possible online, which is particularly important for trainees who have to reconcile work with learning [9, 10]. Hands-on use of the technology is also indispensable, but it requires hardware and software (in particular a 3D printer with dedicated computer program – slicer) access to which might be for a trainee difficult or impossible. Therefore, possibility to use a 3D printer for making own printouts by the trainees should be provided.

A proper methodology should be followed to develop a course on 3D printing which meets requirements indicated above. An example of such methodology is development process of the 3DSPEC course the aim of which is gaining by trainees a competence in practical application of 3D printing technology in their professional practice, presented in the article. Four areas of professional operation were taken into account (target groups), thus diversity of trainees' needs was also taken into account.

The methodology is a comprehensive approach to development of a course which combines declarative and procedural knowledge for effective understanding of the course content and obtaining required abilities. The presented idea of a course development might by applied or adapted also for other courses, in particular those related with practical application of a given technology in specified tasks.

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The Role of Virtual Reality and Biomechanical Technologies in Stroke Rehabilitation

Joanna Bartnicka[1(✉)], Cristina Herrera[2], Robert Michnik[1], Esteban E. Pavan[3], Paolo Vercesi[3], Enrique Varela-Donoso[4], and David Garrido[2]

[1] Institute of Production Engineering, Silesian University of Technology, Gliwice, Poland
{Joanna.Bartnicka,Robert.Michnik}@polsl.pl
[2] Instituto de Biomecánica de Valencia, Valencia, Spain
{cristina.herrera,david.garrido}@ibv.upv.es
[3] Fondazione Politecnico di Milano, Milan, Italy
{esteban.pavan,paolo.vercesi}@polimi.it
[4] European Society of Physical and Rehabilitation Medicine, Delegate, Complutense University, Madrid, Spain
evarelah@enf.ucm.es

Abstract. The aim of this paper is to present a spectrum of virtual reality and biomechanical technologies that can be potentially used in supporting the rehabilitation of people after stroke, in both clinical and home conditions. The methodology was based on a systematic review of up-to-date, published research works available in Elsevier Science Direct database including peer-reviewed journal articles. As a result, trends, possible promising solutions and gaps in the area of innovative rehabilitation tools for post-stroke patients were recognized and discussed. Particularly, the new knowledge and good practices focused on the applicability of biomechanical systems and Virtual Reality (VR) technologies in stroke treatment were searched, which is the subject of an educational and international Erasmus+ project entitled "Development of innovative training contents based on the applicability of virtual reality in the field of stroke rehabilitation- Brain4Train". The training content, which is one of the project outcomes, will be provided to all interested professionals engaged in post-stroke patients' rehabilitation, in order to make them capable to develop customized rehabilitation programs based on techno-innovative rehabilitation models.

Keywords: Biomechanics · Virtual reality · Stroke rehabilitation Systematic review · International e-learning course · Brain4Train

1 Introduction

Stroke disease, known also as cerebrovascular accident (CVA), is a serious health problem in European Union countries and, actually, around the whole world. In fact, stroke is a leading cause of disability [1], simultaneously being a third main cause of death [2]. A stroke can be caused by two distinct mechanisms according to its pathophysiology: ischemia (85%) and hemorrhage (15%) [3].

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Advanced age is one of the most significant stroke risk factors: the risk of having a CVA roughly doubles for each decade of life after age 55 [4]. However, stroke can also occur in the early age, including young adults [5].

Because of the increasing proportion of elderly people in the population, it is estimated that the number of CVA events in European countries is likely to increase from 1.1 million per year in 2000, to more than 1.5 million per year in 2025 [6]. Taking into account a global tendency to increasing the number of older people, even to more than double by 2050 [7], this phenomenon will touch all the countries around the world.

The most important consequence of stroke occurrence is that it affects different and important aspect of human activities, functionality, social and daily life activities. This results from impairments suffered by post-stroke patients in both motor and cognitive functions. In addition, deficits in attention and memory (short and long term) affect patients after acute or subacute stroke [8]. In consequence, this makes them dysfunctional regarding the performance of instrumental activities of daily living, which causes activity limitation and participation restriction [9]. Especially those which require interactions with the environment and are based on manipulation of objects (e.g. shopping or operating a phone) [10]. Meanwhile, the conventional treatment based on physical and occupational therapies can be very long and labor intensive, mostly requiring time-consuming sessions and incurring high costs [11].

Considering all these negative consequences of stroke, dramatically reducing the quality of life for post-stroke patients and their families, it is urgent to develop effective methods and tools for recovering the patients after stroke in order to make them as much independent as possible. They must be accomplished in a way that preserves dignity and motivates the patient to relearn basic skills that the stroke disease may have impaired, like bathing, eating, dressing and walking, and sometimes, speaking among other.

In this sense, including new innovative methods and tools, based on Virtual Reality (VR) technologies and biomechanical systems, into patient rehabilitation becomes promising and has several advantages over traditional treatments. One of it is the possibility of performing both effective rehabilitation under clinical control and self-rehabilitation at home in a safe and efficient way. The key role in this approach to rehabilitation is the development of such a tool that will be easy and intuitive to use by post-stroke patients and their families. However, in order to implement an appropriate and customized rehabilitation process, it is needed to perform the preparatory activities that include at least such stages as:

1. Acquisition and organization of extensive and up-to-date knowledge on innovative technologies that can support post-stroke rehabilitation covering particularly the previous experiences, implementations, ranges of uses, and achievements in this area, as well as a deep understanding of its physiological foundations;
2. Development of knowledge repositories including scenarios of using innovative technologies according to patient's individual characteristic;
3. Trainings of medical staff who participate in rehabilitation process.

Herein we present the results of the first-stage activities accomplished under the international project titled "Development of innovative Training contents based on the applicability of Virtual Reality in the field of Stroke Rehabilitation" acronym

Brain4Train. The main objective of the project is the development, validation and transfer of Body Knowledge, focused on the applicability of new VR technologies and biomechanical systems, in order to improve treatment of stroke disease, especially in Europe. Content generation will be focused on the main interest areas of the health professionals, especially those related with neurological rehabilitation.

2 Material and Methods

The research material was gathered on the basis of a systematic literature review. The searching activities were performed within Elsevier - Science Direct database that includes a total of 6.159 different journals and books from the health sciences area. Regarding the search strategy, two limitation criteria were defined: (1) type of publication: research articles OR review articles; (2) date of publication: from 2014 to 2018 (preference was given to the last five years, in order to review the newest knowledge only). The basic search algorithm was "rehabilitation AND virtual reality". Then, a second search was accomplished after adding also the keyword "stroke". Finaly, a third search was carried out within the previously found references, and the additional term "biomechanics" was included to further focus on the principles behind VR-based rehabilitation.

All titles, abstracts and the whole article content, if needed, were analyzed in order to have sure they meet the main objective and subject of the research.

For the analysis purpose, a spreadsheet was created that represents a research matrix allowing for statistical calculations. The matrix includes the following components:

- title of a paper,
- year of publication,
- title of the journal,
- country of origin,
- subject of research.

In addition, a critical analysis of the peer-reviewed literature was performed in order to find answers to the following research questions:

Q1. What kind of innovative tools mainly support rehabilitation of post-stroke patients?
Q2. What are the main support areas regarding using modern technologies in rehabilitation?
Q3. Are there repetitive tools or final products supporting post-stroke rehabilitation which indicate the popularity of a given solution or indicate some trends in product development?
Q4. What is the phase of product development regarding post-stroke rehabilitation?

3 Results

From a basic, unfiltered search, 3.913 references including all article types were identified. After excluding references different than Research article or Review article, the number of relevant articles decreased to 2.301. Among them, 1.013 papers were published from 2014 until 2018. The second search identified 126 references that were further analyzed to verify the topic relevance. As a result, 74 articles met the searching criteria and were included in this review (they composed the final sample group. Among them, 18 articles included additionally the term "biomechanics". Figure 1 presents the scheme of the study selection.

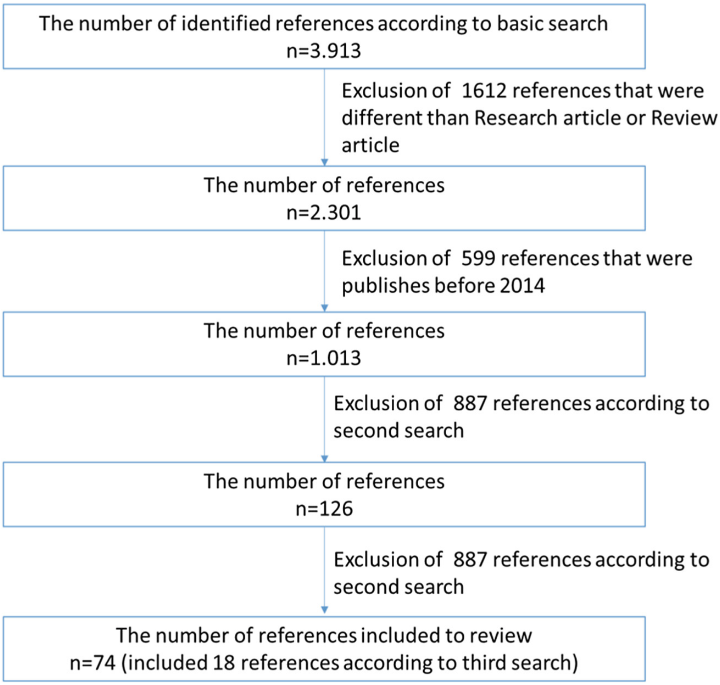

Fig. 1. Scheme of the papers' selection

Taking into account the overall quantitative set of results, a summary list including a profile of the research sample was described in Table 1.

Table 1. Research sample in numbers.

Number of journals	Number of countries from which the article comes from	Number of support areas	Number of technologies (apart from VR and biomechanics) used in rehabilitation
n = 36	n = 21	n = 10	n = 3

A total of 36 different journals were recognized, whose scope includes topics on post-stroke rehabilitation with reference to VR. However, at the time the research was performed, only one journal issued more than 10 papers in the explored area, namely the Journal of Stroke and Cerebrovascular Diseases.

Figure 2 presents a list of twelve journals, in which more than one paper on the relationships between post-stroke rehabilitation and VR was published.

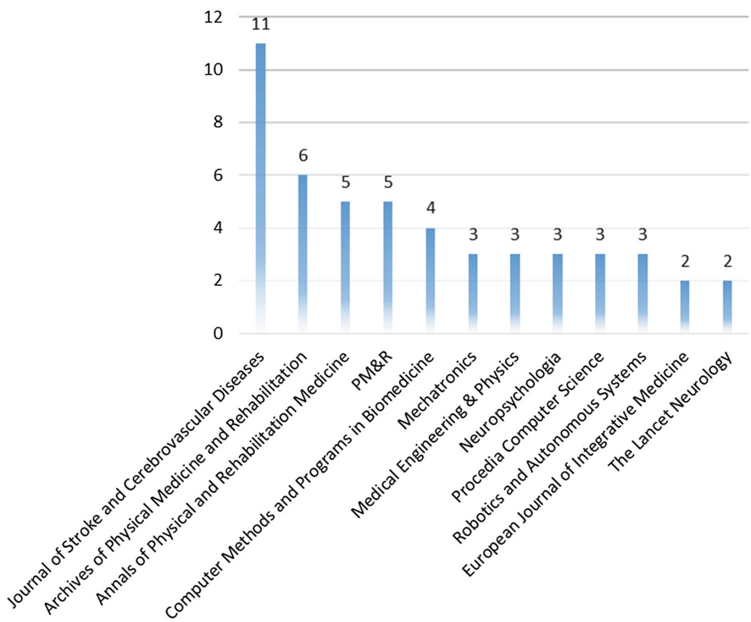

Fig. 2. The total number of published articles by journal

Regarding the papers' country of origin, the published researches on post-stroke rehabilitation performed by using VR, were carried out in 21 countries, mainly located in Europe. Among them, the most active countries are located in Southern and Western Europe, like Italy, Spain and France. However, the largest number of papers was from Korea. Instead, it was found only one reference from the whole African continent. Figure 3 presents a map showing those countries where two or more papers on this research field were published.

Statistics showed that there is a trend of increasing interest in the subject of innovative rehabilitation in the recent years, which is represented by the number of reported studies in this area within the last five years (Fig. 4).

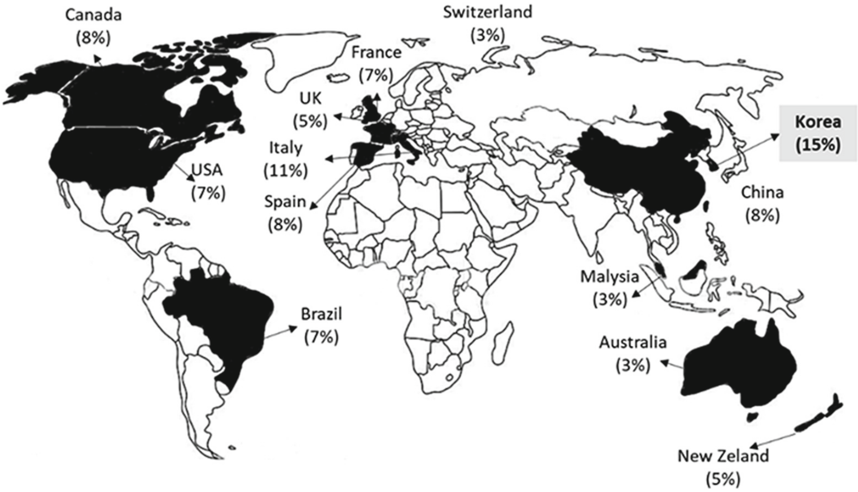

Fig. 3. Geographical distribution by origin of the articles

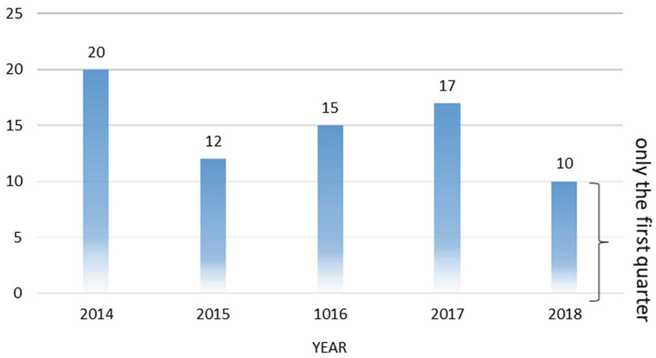

Fig. 4. Distribution of articles by publication year

Regarding how VR is used in post-stroke rehabilitation practice, nine different research subjects were recognized. In the most common cases, studies were related to the strengthening of motor skills, mainly of upper limbs (43% of studies) and, additionally, hand and fingers (8%). Instead, other studies focused on the enhancing of gait and keeping balance. Other important rehabilitation areas, which can be supported by innovative technologies, include a series of higher brain functions, like cognitive and navigation skills in post-stroke patients, as well as the recovery of memory abilities. Figure 5 represents the distribution of the different studies' subject.

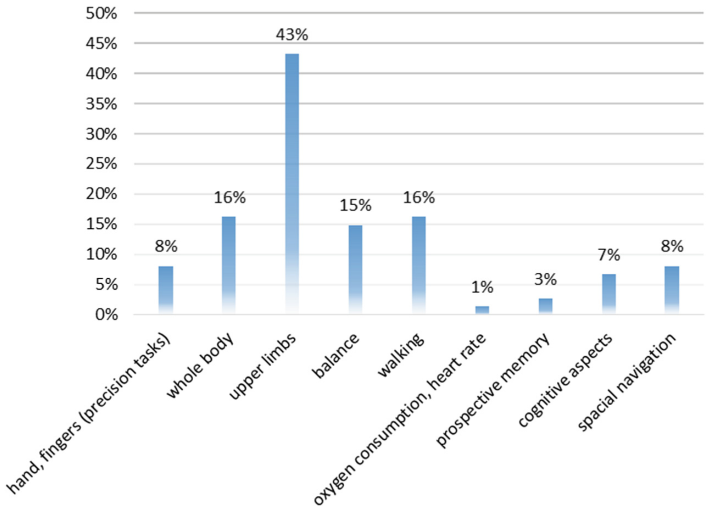

Fig. 5. Distribution of papers by studies' subject

4 Discussion

The statistical analysis of these references suggests that innovative VR and biomechanical technologies, though very promising, is still a relatively new approach in the rehabilitation of post-stroke patients. It is significant that the origin of most of the published papers indicates Korea in the first place, demonstrating a strong interest in the creation of new technologies for post-stroke rehabilitation. Since the population in Korea is aging very fast (among the Organization for Economic Cooperation and Development (OECD) countries, Koreans are the fastest aging population), stroke burden is predicted to be substantially increasing in the near future. Being a country with a great economic growth over the past half-century, stroke research in Korea is one of the most advanced in the world [12]. Particularly the research are focused on using VR and Augmented Reality (AR) in supporting motor abilities of post-stroke patients, mainly in reference to upper limbs [13–15]. It is worthy to add that these researches were based on clinical trials and provide quantitative information on the impact of virtual technology on the effectiveness of the process of rehabilitation of upper limbs.

Apart from Korean research activities, by taking into account the whole sample of articles, it appears that most published studies focused on upper body rehabilitation. This results from the fact that complete or partial loss of mobility in an upper extremity is the most commonly reported impairment in the stroke patients (77.4% of all cases) [16, 17]. At the same time, such kind of dysfunction may hinder the performance of activities of daily living (ADLs) and significantly undermine the quality of life [11, 18]. Therefore, the improvement of upper limbs function remains a major subject of research and that is reflected in the large number of studies included in the papers sample (43% of all articles). The need of developing new solutions for supporting recovery is very important because some estimations report that 30–60% of adult patients after stroke do not achieve a satisfactory motor recovery of the upper limbs, despite intensive rehabilitation [19]. Particularly, the VR technologies were used to support the rehabilitation of tasks performed by hand and fingers [11].

Apart from upper extremities, there were recognized studies carried out with the use of VR in supporting balance and walking. Especially in these reported studies, particular devices were verified based on VR games. One of it is the VR training using a popular Xbox Kinect – based system. Based on the examination of patients with chronic hemiplegic stroke, for whom several trainings were dedicated, it was concluded that this tool may bring effective therapeutic results regarding motor functions of the whole body, specifically balance abilities [20]. Another use of Kinect system was presented in [4], where the patented software Motion Rehab AVE 3D, which incorporated exercises including six different activities in a 3D space, was described. These studies aimed at mapping a basic and comfortable setup of equipment in order to adjust its functionalities, interface and interaction process to patients expectation, particularly from the point of view of their motivation to making exercises. All the participants taking part in the experiments classified the interaction process as interesting and appropriate for their age, presenting a good acceptance.

Similar products were also used: Nintendo Wii, was analyzed as possible supporting tool for improving motor functions of the post-stroke patients [21]. Despite the fact that the studies did not unambiguously ensure the effectiveness of the treatment with the use of Nintendo Wii console as a whole, there were few reported examples of motor functions improvement in post-stroke patients taking part in experimental therapy programs. Also another product, namely Tetrax, a biofeedback video game system (Tetrax Ltd) including 11 games was tested when used for balance training [22]. The reported preliminary results confirmed the possible support that can strengthen conventional therapy in people after stroke.

All reported experiments based on video games are at the development level. However, the greatest benefit of using this unconventional therapy is the motivational force that is extremely important for people needing intensive motor training. Normally, patients tend to get tired and find the trainings monotonous [4]. This often leads to the loss of motivation in rehabilitation, whilst the motivation is one of the main factors influencing the plasticity of the Central Nervous System (CNS) [23]. Games can partially replace normal life due to the performance of natural movements instead of repeating the same movements. Another positive aspect of using games is the relatively simple customization of training according to the patients' abilities.

Apart from VR games, other promising technologies that are now being rapidly developed in the rehabilitation sector, are based on the use of robotics and exoskeleton (i.e. powered, wearable mechanisms). These technologies support motor function recovery, including also walking, and can be customized to particular patient's characteristic [24–26].

Summarizing, the studies presented above, and most of the studies on using VR in post-stroke rehabilitation, are focused on the functional recovery of the patients. However, in order to make the new solutions safe for patients, especially when rehabilitation is performed at home, it is needed to develop monitoring or control systems that are able to assess the progress of trainings, give some feedback to the patient, and first of all inform him/her about possible threats when exercising (e.g. referring too large deflection of joint angles). To this end, the biomechanical systems should be simultaneously developed and integrated to support VR applications. In the published research works, it was noted that only 18 papers described, or at least mentioned, the biomechanical approach followed by the VR tools. This important information should always be provided, because it can directly influence the effectiveness of VR-supported rehabilitation. Instead, they were always described in the context of robotic or exoskeletal technologies. Meanwhile, the biomechanics achievements in other VR-assisted solutions for post-stroke rehabilitation (like sport VR game or VR scenarios for daily activities) are still missing. This aspect is crucial when thinking about standardizations in VR based rehabilitation.

Another important area that is insufficiently supported by VR, is related to improving the cognitive function in post-stroke patients. Among the papers analyzed, there were only 5 papers that deal with this aspect of stroke rehabilitation and 6 papers on spatial navigation. Also, memory is a rare subject of research in the context of using innovative technologies (2 papers only were recognized).

5 Conclusion

From this literature review, a growing interest was evident, of both clinical and research fields, on the use of innovative tools in the rehabilitation of post-stroke patients, demonstrating the utility of new technologies in the recovery of impaired movements and the associated functions. There were mainly two tools or equipments that support rehabilitation of post-stroke patients that can be transferred to final and commercial products: (1) VR games based on VR consoles like Kinect system and Nintendo Wii, although there was no clinical verification of the usefulness of these technologies; (2) robots or exoskeleton that are integrated in biomechanical systems. The main area supported by modern technologies in rehabilitation regards the improvement of motor functions of upper body, while the restoration of lower limb function is still being developed. Basically, the rehabilitation in people after stroke, which is effectively supported by the innovative technologies, is relatively little recognized, especially when compared with the use of biomechanical assessment systems. Also such areas like cognitive rehabilitation and memory trainings are uncommon subjects of support by the VR devices available.

The information gathered from this work is also very important when developing trainings for health professionals, mainly rehabilitators and physiotherapists, because of the need to provide up-to-date content on the different possible ways that the new technologies can enhance the rehabilitation process, not only in post-stroke survivors, but also in people suffering from many other disorders.

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OVOMAX Online Course as a Way to Improve Competencies and Qualifications for Designing and Manufacturing of Custom-Made Orthopaedic Implants

Jarosław Tokarczyk[1(✉)], Marek Dudek[1], Olga Jordá[2], Elkin Martinez[2], Andrés Peñuelas-Herráiz[3], and Víctor-Javier Primo-Capella[3,4]

[1] KOMAG Institute of Mining Technology, Gliwice, Poland
{jtokarczyk,mdudek}@komag.eu
[2] AIDIMME Instituto Tecnológico Metalmecánico, Mueble, Madera, Embalaje y Afines, Paterna, Valencia, Spain
{ojorda,elkin.martinez}@aidimme.es
[3] Biomechanics Institute of Valencia (IBV), Universitat Politècnica de València, Valencia, Spain
{andres.penuelas,victor.primo}@ibv.org
[4] Health Care Technology Group, Biomedical Research Networking Center Bioengineering, Biomaterials, Nanomedicine (CIBER-BBN), Valencia, Spain

Abstract. The paper presents an open and international online training course for design, manufacture and validation of custom-made orthopaedic, oral and cranio-maxillofacial devices. Based on the initial international survey, the innovative approach of this course presents all main steps of designing and production process of custom-made devices including medical imaging, surgical planning, product designing, mechanical and functional simulations, material selection and manufacturing process with particular emphasis on quality assurance systems, standards and regulations. Proposed on-line course offers the wide audience of medical device designers a worthy education and training, along their professional career. This approach of transferring knowledge between students – academic tutor, can be also successfully used to improve practical skills of professionals in a form of case studies.

Keywords: Custom-made implants · Orthopaedic implants · International E-learning course · OVOMAX

1 Introduction

The global market for 3-D printing in medical application was valued $354.5 million worldwide in 2012 and is expected to grow at a compound annual growth rate (CAGR) of 15.4% from 2013 to 2019 to reach $965.5 million by 2019 [1]. Considering that Europe dominated the additive manufacturing for medical devices market in 2012, these economic forecasts augur a promising future for those European Medical Device manufacturers that decide to incorporate design and manufacture of customized implantable

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devices to their portfolio. This situation will result in the incorporation of specifically trained professionals or in the training of the existing staff.

The production process of custom-made medical devices can be summarized in three main steps [2, 3]: 1. Design of the medical device (CAD) from medical imaging obtained mainly by CT or MR; 2. Validation of the device. Custom-made design must be validated to assure meeting the mechanical and functional requirements. This validation can be performed by using numerical methods like FEM or other computational methods; 3. Manufacturing process of the device. In the case of additive manufacturing techniques, prior to start with manufacture process the CAD of the device must be adapted, incorporating the necessary support structures for the device manufacture.

Creating custom-made medical device models requires the skills that many designers do not usually have. While many of the newer, additive manufacturing machines do not require significant skill to operate, preparation of the files and some post-processing requirements may require more ability.

2 Materials and Methods

Training on additive manufacturing is crucial in the design phase. The development of custom-made implants due to the individual anatomic features of patients requires a complicated design and construction process than it is realized in the case with traditional design. Each of individual steps of this process requires high specialization and knowledge from the user. At the same time, general information about the whole process is required from specialists. The proposed course combines these two features as a useful way to increase knowledge within the presented topic area. Nowadays, it is popular that specialist knowledge (i.e. surgery training) is shared by e-learning courses [4, 5].

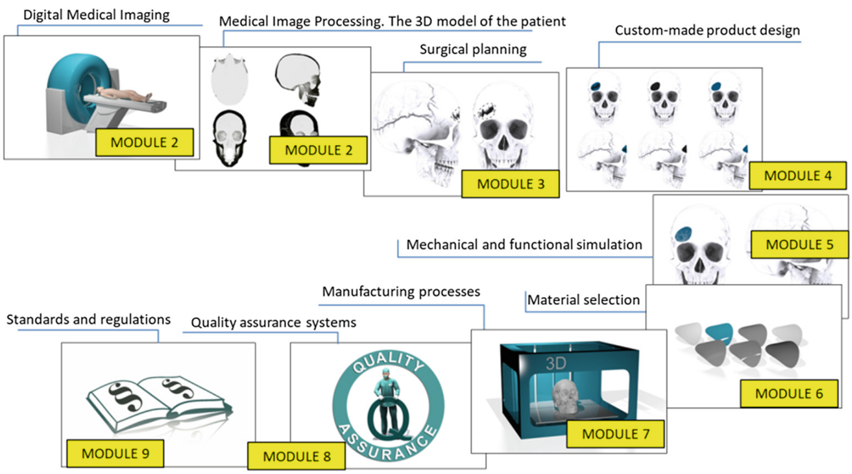

Fig. 1. Thematic modules of the proposed method [6].

OVOMAX course is divided into nine modules, Fig. 1. Module 1 is an introduction to the course. It briefly discusses further modules of the course and does not have a self-evaluation section.

Modules 2 to 9 contain didactic content, complementary materials and self-evaluation activity: Didactic content – cover the main content of the course – objectives, introduction, working sessions and key-ideas (summary); Complementary materials – cover the additional information to enrich the course and allow students to widen their knowledge; Self-evaluation – covers questions from the didactic content, which allows checking the level of knowledge acquired by the student.

3 General Steps for Obtaining a Custom-Made Implant

All products placed on the market are subjected to a number of different regulations that lay down requirements, which must be met during the whole life cycle of those products. This regards also the medical devices for which such requirements are separately determined. Implants used in maxillofacial surgery are implantable medical devices. The main legal act related to medical devices is Council Directive 93/42/EEC of 14 June 1993 on medical devices, referred to as MD Directive. There is a new regulation approved by the European Parliament and the Council concerning the medical devices (Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EEC and 93/42/EEC). It was approved in 2017 and will be mandatory in 2020. Regarding the conformity assessment and according to this regulation, manufacturers of custom-made devices shall follow the procedure set out in Annexe XIII and draw up the statement set out in Section 1 of that Annexe before placing such devices on the market. The health sector is one of the most demanding sectors in the world because of the risk to human health. One of the most important pillars on which health is based on, is health technology, so it is necessary to work through better management, more efficient, synchronized with the advancement of technologies, optimizing systems and minimizing their risks. These criteria are collected in the ISO 13485 Standard. This standard is particularly important for quality management system for manufacturers of medical devices, which was developed to be the vehicle for alignment of quality management systems in the medical device industry. Below general steps for preparation of custom-made implant are given.

3.1 Patient Data Capture Methods and Formats – The 3D Model of the Patient

The first step for obtaining a custom-made implant is to create a 3D model of the patient. The process is divided into two phases: creating the anatomical structure of the patient using digital imaging (diagnostic imaging's methods) and creating 3D model of the patient using segmentation process.

Diagnostic imaging is the technique and process for creating the visual representations of the body interior for clinical analysis and medical intervention, as well as visual representation of the function of some organs or tissues. Seeks to reveal internal structures hidden by the skin and bones, as well as to diagnose and treat disease. The following methods of diagnostic imaging are used: Radiography (X-ray); Angiography (X-ray); Ultrasonography (USG); Computed Tomography (CT) and Magnetic Resonance Imaging (MRI).

Computed Tomography is the most appropriate method of medical imaging to create a model of a patient's head. The use of Computed Tomography allows visualizing and saving the spatial skull model. By using Computed Tomography, it is possible to construct a patient's skull pattern that takes into account the individual physiological characteristics of the patient.

Medical imaging techniques take measures of local physical properties and relate them to pixel intensity values, as a result different anatomical structures can be distinguished in a pixmap. The output data from diagnostic imaging for further processing are stored in the form of a DICOM file format. DICOM file format is an open international standard for storing and communication of medical images and other related digital data. It includes a file format definition and a network communications protocol. The main purpose of the DICOM standard is to allow cross-vendor interoperability among devices and information systems dealing with digital medical images.

Most image processes (to create a 3D model of the patient) start with the extraction of the voxel sets representing the relevant anatomical structures. This process is called segmentation and is fundamental for surgical planning, 3D printing and numerical simulation. In the case of volumetric images, segmentation makes it possible to transform a 3D matrix of colour information into a 3D shape. Segmentation makes it possible to obtain an anatomical model from a volumetric medical image. A variety of segmentation methods (automatic, semiautomatic or manual) are available. In the general case these tools have to be used together to obtain the desired result. Several segmentation applications are available under commercial (Amira, AnalyzeDirect, Materialise Mimics, simpleware, TurtleSeg) or free software (itk-Snap, OSIRIX, INVESALIUS, 3DSlicer, ImageVis3D) licence types.

The following operations can be distinguished in the segmentation process, Fig. 2: Thresholding – to create binary images from a grayscale image; Region growing – to create a single connected domain; Slice editing – to remove artefact; 3D editing – to add or remove groups of pixels from the 3D reconstruction of segmentation mask; Boolean mask tool – to perform Boolean operation on masks such as merging, subtraction or intersection – these can simplify the segmentation process; Crop mask – to simplify the manipulation of the mask for the user and to reduce the computational cost of further processing and Image enhancing filters – to apply filters to the image before the segmentation starts.

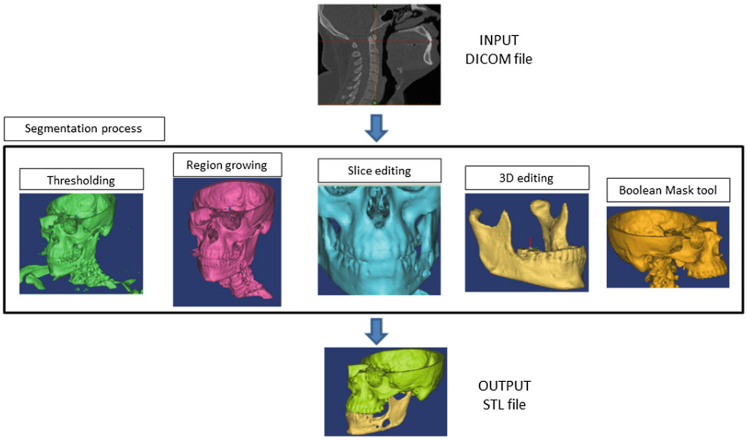

Fig. 2. Example of segmentation process – from medical imaging (DICOM) to 3D file (STL) – mandible and cranium segmentation [6].

3.2 Surgical Planning

Preoperative templating gives surgeons the possibility to plan procedures meticulously before actually carrying them out. Surgical planning, that is crucial in surgical workflow optimization [7], also includes the selection of the medical instruments to be used during the procedure, and when required by the procedure complexity, the design and manufacturing of patient specific tools, such as bone cutting guides.

In the preoperative planning procedures, an STL format file (Stereo Lithography interface format), created after the segmentation process, is used. The STL meshes are usually processed by a number of enhancing tools before it can be used. The STL file can be used to create physical models by 3D printing and introduced into dedicated software to carry out virtual surgical planning.

Surgical planning can be divided into two phases: creating the physical model and creating the virtual model. During creating the physical model, the following functions are used, Fig. 3: Smoothing – to reduce the mesh noise; Wrapping – to close small holes or filter small inclusions; Filling – to fill holes in the model; Stitching – to eliminate small gaps between triangles; Reduce – to reduce the number of mesh's elements; Filter Sharp triangles – to detect and merge together triangles having an angle value below a certain threshold and Overlapped triangles – to detect overlapped triangles and correct them.

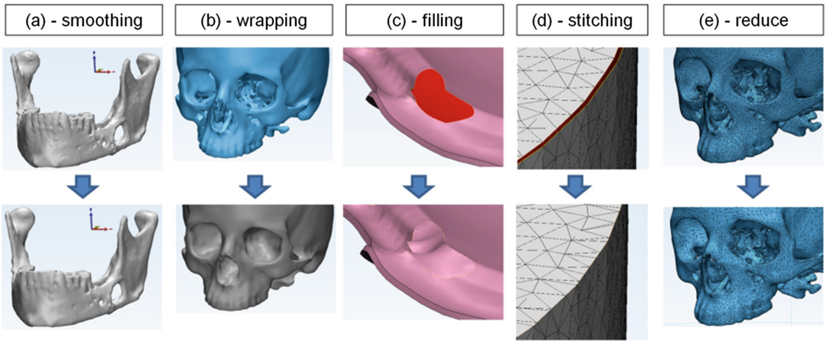

Fig. 3. Example of surgical planning – creating the physical model: – smoothing of STL mandible model (a); wrapping of STL skull model (b); hole filling of STL model (c); surface stitching in STL model (d) and facet reduction in skull STL model (e) [6].

STL file is the most common format for 3D printing. The information contained in STL represents the external surface of a solid object as an assembly of plane, triangular facets and is structured as a series of records. Each record refers to one of the facets and contains the three Cartesian components of the facet unit normal vector and the Cartesian coordinates of the vertices.

Therefore, 3D printing is particularly suitable for the creation of patient specific models base on medical images. In the case of surgical planning these models are usually made of polymeric materials. The main available technologies are: Extrusion: Fuse deposition modelling (FDM), Fused filament fabrication (FFF); Light Polymerization: Stereolithography (SLA), Digital light processing(DLP); Continuous liquid interphase production (CLIP) and Powder bed: Powder bed and inkjet head 3D printing (3DP), Selective heat sintering (SHS), and Selective laser sintering (SLS).

Virtual models are the other way of preoperative planning that reduces the possibility of complications and improving the surgery precision. They are created within dedicated software environment that enables to create patient-specific anatomical models based on volumetric images. Surgeons can move through the anatomical structures shown in these models and use them to design patient-specific instrument guides to be printed and used in the operation room.

Most typical applications of virtual planning are in dental medicine and maxillofacial surgery. In many cases, especially for big companies, implant manufacturers not only offer the physical devices but also the surgical planning software and, in some cases, patient-specific medical instruments.

3.3 Custom-Made Product Design

When designing a custom-made implant, different requirements must be taken into account that will finally allow the implant to perform its intended function, to be produced by the suitable technologies and to meet current regulations required for commercialization.

Custom-made orthopaedic, oral and cranio-maxillofacial devices are intended to replace or help in the consolidation of a damaged body part. For that reason, implants must be designed according to the biomechanical characteristics of the body part they replace or are attached to, Fig. 4.

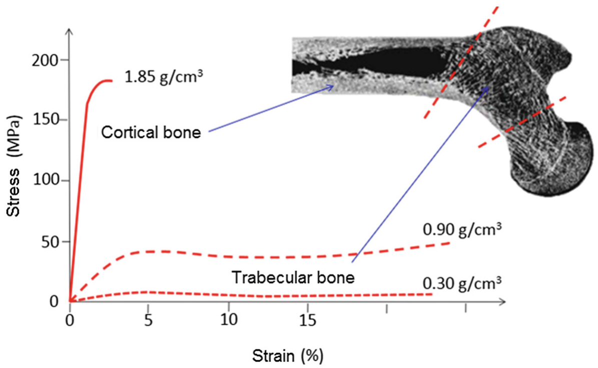

Fig. 4. Traction test of cortical and trabecular bone [6].

Although the scope of biomechanics is very extensive, the requirements can be gathered into the following three groups: 1. Geometrical and mechanical properties of the bone and surrounding tissues; 2. Kinematics; 3. Loads and stress distribution.

There are other requirements, which cannot be classified within above groups. However, they are necessary for the functionality of the prosthesis. Some examples are shown as follows: The medical device must be seen by medical imaging during or after the surgery (i.e. radiopaque materials); The medical device must be easy to implant by surgeons (i.e. holding or adjustment systems of prosthesis, related to special surgical instruments); The medical device can be adapted to the patient, prior or during the surgery (i.e. by means of the system adjustment).

For some implants, maintaining as much as possible the original aesthetic characteristics is important. This is the case of the products intended to reduce or remove deformations such as cranial and maxillofacial reconstruction implants.

Custom-made implant materials must have adequate properties to satisfy the biomechanical requirements, functionality, biocompatibility and requirements for processing by additive manufacturing technologies. Materials must allow osteoinduction and osteoconduction in order to reach an optimal grade of osseointegration in the case of implant surface coatings or bone substitutes. Material and surface treatment are determinant to avoid wear and ensure an extended lifetime of the product.

At present, additive manufacturing technologies have been introduced as an important alternative to produce certain products or as a production process in combination with other manufacturing technologies. Main limitations of this technology are the resolution and materials available. All materials intended to replace bone tissue must satisfy its biocompatibility and in this case integration with the bone is needed, then meeting the osteoconduction and osteoinduction requirements is also necessary, Fig. 5.

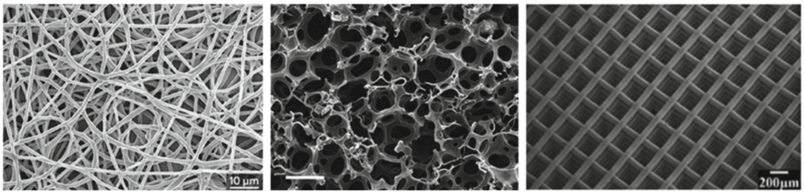

Fig. 5. Scanning electron microscopy images of different scaffold structures [8–10].

A custom-made implant, as other medical devices, has to be adapted for sterilisation by the current protocols such as autoclave, ethylene oxide and gamma-ray irradiation. The sterilization process must not cause any loss of mechanical, chemical or geometrical properties due to the low melting point of polymers, complex geometries or hydrolytic degradation mechanisms. The final product must also withstand the radiation effect regarding degradation or loss of properties. This is the case of tumor resections, which require a radiotherapy treatment.

Design process of a personalised implant within CAD software is carried out in two ways: *Parametric design* and *Anatomical design*. The first one is for designing an implant not for a specific patient, but which allows modifying its dimensions in order to adapt it as much as possible to a patient's anatomy. It enables quite easy modification of the design, i.e. after having detected a failure in a finite elements analysis. The second case is for designing an implant for a specific patient based on the 3D reconstruction of his or her real anatomy. In this case, the implant is designed directly to the patient's reconstructed anatomy, which allows a perfect contact between implant and bone. The result is a perfectly reproducing the patient's bone surface for aesthetics purposes (e.g. in cranium reconstruction). Design complexity and difficulty in implementing the changes is the main limitation.

3.4 Mechanical and Functional Simulation (FEM)

Verification and validation of engineering designs are of primary importance as they directly influence production process and ultimately define product functionality and customer perception. In order to reduce the number of real objects tests and to cut the cost and time of certification of the structural systems, the Finite Element Analysis (FEA) technique is employed to predict the possible behaviour of real products until their failure.

The first stage of FEA is the discretization process, which includes the real-life structural design problem and turns it into an idealized mathematical model, the Finite Element Model (FEM). The second stage involves selecting the appropriate finite elements, mesh layouts and solution algorithms to define the structural behaviour of the idealised mechanical system.

Preparing of computational model consists of the following steps: Discretization of the geometrical models – finite element mesh creation; Development of boundary conditions; Preparing the load cases; Preparing the models of materials and the property of the computational model; Preparing input data for the analysis. Selection of the type of analysis; Results presentation.

Discretization process of geometrical model is the first stage of preparing the computational model. The quality of the finite element has a decisive impact on the results of numerical calculations. Discretization process could be a time consuming and requires an experienced specialist. In the virtual prototyping process, the numerical strength analysis and the computational model include both implant, which constitute the missing bone structures and elements connecting it with the existing bone structures. Depending on the software (preprocessor), there are various types of finite elements: curve, surface and solid. Very often, the meshing process is carried out in an automatic way. However, sometimes the iterative approach is needed until the proper FEM mesh is created. Number of finite elements and nodes determine accuracy of the results, in particular in those parts of the calculation model, in which there are discontinuities in the form of bends, curves and small holes recesses. Disadvantages of the excessive computational model are difficulties in its editing in the preprocessor and a long time of numerical calculations.

Definition of the boundary conditions is one of the major and difficult steps in creating the computational task. It includes the relevant interactions between the computational model and its environment. Boundary conditions have a decisive impact on the quality of numerical calculations results and they are the most common reason of errors. Defined load conditions require applying force fields to the selected nodes. They simulate active influence of the environment on the computational model.

Identification of the material properties of the bone and the material properties of the implant is necessary for numerical simulations of strength of implants and how they are fixed. Young's modulus and Poisson's ratio are the main properties of the material, which describe the behavior of the implant subjected to load. These parameters also allow to evaluate the cooperation of the implant with the bone. Results of strength calculations are usually presented as coloured maps superimposed on the evaluated calculation model. The results are presented in the form of displacements maps, maps of reduced stresses, values of constraint forces, etc. Displacement vectors are added to coordinated points of FEM grid, which gives visual effect of the deformed model. When evaluating an implant, displacement vectors caused by the external loads inform about implant stiffness. For complex calculation models, displacement values are presented in local reference systems, e.g. displacement of a screw – map of displacement of implant caused by pressure from the skull inside, Fig. 6.

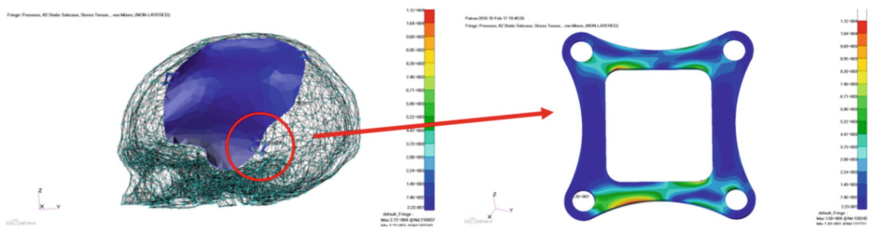

Fig. 6. Map of reduced stresses in implant with stabilizing elements [6].

3.5 Materials

There were many attempts in the early 1920s to extend the use of biomaterials despite their limited availability and the lack of knowledge regarding their safety and performance. In the 1960s, the term "biocompatibility" appeared to refer to which extent the living tissue was tolerant to a foreign implanted material. In the last forty years, there has been an exponential increase in the publications related to biomaterials in the scientific literature and in the reports from clinical tests. This led to development of new implants and surgical procedures that have remarkable improved healthcare quality. According to multiple criteria, biomaterials may be classified in many different ways. The most relevant classification is presented in Fig. 7.

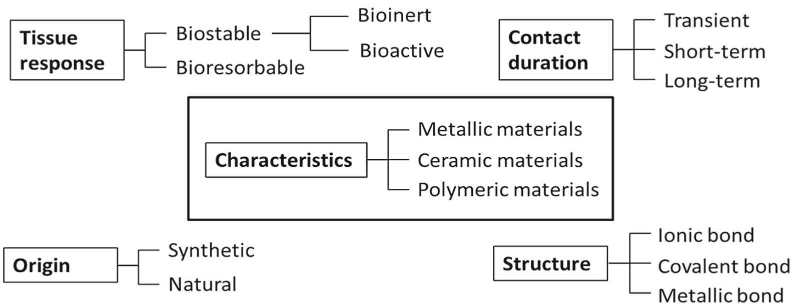

Fig. 7. General classification of biomaterials [6].

Biomaterials are the essential components of medical devices and implants; thus, they need to be thoroughly evaluated and tested to ensure safety and performance of the whole device. Current harmonised standards related to biomaterials for product development and management are as follows: ISO 13485, ISO 14155, ISO 14971 and ISO 10993 series.

A biodegradable material can be chemically degraded or decomposed, so it should maintain its mechanical properties until it is no longer needed and then be absorbed and excreted by the body, leaving no trace. Current commercial biodegradable devices include: poly(lactic acid) (PLA), poly(glycolic acid) (PGA); chitosan and hyaluronic acid.

Sterility is the state of being free from viable microorganisms and sterilization is defined as the validated process used to render product free from viable microorganism. The ideal method for sterilization would have the following features: Short cycle time; Compatible with all types of materials (metallic, ceramic, polymeric…); No need for aeration/isolation (quarantine); Sterilization agent penetrates and reaches all surface areas; No residues and low cost.

The most popular types of materials implants manufacturing are the following materials: polymeric, metallic and ceramic. Polymers are macromolecules (usually organic) formed by the combination of smaller molecules called monomers in a reaction called polymerization. When the polymer originates from a single type of monomer is known as homopolymer, whilst it is derived from two or more different types of monomer it is known as heteropolymer. Properties of polymers are determined by different factors: spatial structure, molecular weight and degree of crystallinity. Metals are used as biomaterials due to their good mechanical, electrical and thermal properties. As seen before, atoms in metallic materials are linked by metallic bonds and this network of metallic bonding allow the electrons to freely move within it. Metals and metal alloys are often used as complement or replacement component for hard tissue giving their favourable mechanical properties, such as for hip and knee joint replacements, to repair a damaged bone (internal fixation) by means of bone screws and metal plates, pins or rods. Many other applications include dental implants, orthodontic wires, vascular implants, catheter guidewires, etc. Ceramics are polycrystalline, non-metallic inorganic compounds formed from metallic (Al, Mg, Na, Ti, W) and non-metallic (O, N, C) elements.

3.6 Manufacturing Processes

According to ASTM F2792-10 standard, additive manufacturing technologies are defined as the process of joining materials to create objects, usually layer by layer, from 3D model data, as opposed to subtractive manufacturing technologies. Generally, applications of AM technologies are divided into four categories: prototypes, masters, products and tools. Prototypes – it is possible to manufacture prototypes for functional, dimensional or aesthetic evaluation and to speed up some steps in the product designing process, for example the design of the packaging before disposing of the final product. Master – it is possible to manufacture master models for other manufacturing processes such as vacuum casting or investment casting. Products – it is possible to manufacture directly a final part or final product with the desirable requirements, such us an implant or a cutting guide. Tools – it is possible to manufacture industrial tools, such as moulds and males with conformal cooling, etc.

After the verification of the STL file, the volume of the part is divided into thin layers; this process of layering is performed in a software specific to these types of technologies, as Magics from Materialise or Autodesk® Netfabb®. The file that contains all layers is transferred to the 3D printing machines, for which the manufacturing parameters are assigned (the way to assign the process parameters differs depending on the additive manufacturing technology) to start the manufacturing process. When the part is manufactured the machine stops and the part is taken out from the machine by an operator. Supports are removed and the post processing requires the part finishing.

Additive Manufacturing technologies are classified depending on the material and the steps: *Direct* when models or parts are constructed in an additive manufacturing machine or *Indirect* when models or parts are built after several stages starting from a master manufactured using additive manufacturing technology. Processes like vacuum casting and investment casting are included in this category. Examples of products created by additive manufacturing technology are presented in Fig. 8.

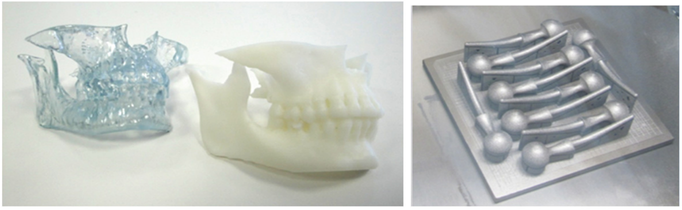

Fig. 8. Additive manufacturing examples [6].

There are numerous polymer additive manufacturing technologies, such as Thermoplastic Extrusion (FDM), Thermostable printing (Inkjet printing), Solidification of thermostable polymers (SLA, DLP), Fusion of Thermoplastic Powders (SLS), Multijet Fusion (HP). Regarding the metal additive manufacturing technologies, they are the most innovative but there are not as many construction techniques as for polymers, the most important techniques are based on the fusion of metal powder. The heat source that allows the fusion is crucial for Selective Laser Melting (SLM) or Electron Beam Melting (EBM) processes.

4 Conclusions

The discussed methods are described and disseminated in a form of e-learning course on a professional knowledge platform that improves competencies and qualifications for designers and manufacturers of custom-made orthopaedic implants. The proposed e-learning course extends the training of designers in the field of custom-made medical devices, covering customized design of devices based on medical imaging, validation and manufacture using additive manufacture technologies. The course is addressed to technical staff of medical device manufacturers, enabling their incorporation in the potential market of custom-made medical devices. In addition, developed course can also be addressed to product engineers and designers aiming at completion of their academic and professional education, thus becoming potential new employees in medical device industries. ICT tools used to develop a course are the accurate solutions for wide audience of practitioners. Online knowledge transfer in the line student – academic tutor, can be successfully used for improving their practical skills. The online course is available in four European languages (English, Spanish, Polish and Hungarian) in order to increase acceptance of the course. The course is offered online to be suitable for active professionals and for students following formal education courses, so they can "attend" the course at any time, from anywhere.

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A Study of Learning Effectiveness in Disaster Nursing Course Based on Kirkpatrick's Evaluation Model

Jing-Shia Tang[1,2], Chien-Liang Chen[3], Chia-Chang Chuang[4], Chia-Jung Chen[2], and Jui-Ying Feng[5](✉)

[1] Department of Nursing, Chung Hwa University of Medical Technology, Tainan, Taiwan
[2] International Doctoral Program in Nursing, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[3] Department of Physical Therapy, I-Shou University, Kaohsiung, Taiwan
[4] Department of Emergency Medicine, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[5] Department of Nursing, College of Medicine National Cheng Kung University, Tainan, Taiwan
juiying@mail.ncku.edu.tw

Abstract. This study aims to evaluate the course of disaster nursing through assessing nursing students' satisfaction, knowledge and skills gain and impact on practices by the Kirkpatrick's evaluation model. Seventy undergraduate nursing students were surveyed. The study adopted the Kirkpatrick's evaluation model which contains four levels. Data were presented by descriptive statistics, Person correlation and t-test to conduct the analysis. Level 1 "Reaction", the significant positively correlation existed between course satisfaction and teaching strategies. Level 2 "Learning", post-test data was significantly higher than pre-test data. There was positively significant correlation existed between level 3 (Behavior) and level 4 (Result). Our course programs can be used as a reference for future nursing schools offer related courses to prepare the implementation of disaster nursing courses and teaching methods, establish suitable disaster nursing education programs for our national conditions.

Keywords: Disaster nursing course · Kirkpatrick's evaluation model Nursing students

1 Introduction

In recent years, natural disasters and man-made disasters have been reported in various parts of the world more frequently. Disaster nursing courses have become an indispensable part of the nursing education. In response to the trends and needs of development of nursing, the International Council of Nurses [1] suggests that nursing schools should prioritize disaster nursing as a basic component of nursing education so as to enhance students' disaster nursing-related knowledge. The 21st century education

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system of today emphasizes a form of student-centered learning that provides a more effective learning environment for students [2], in which the process of teaching starts with the student [3]. In addition, the education system places an emphasis on students' learning outcomes that helps students learn effectively as the ultimate goal [4]. Disaster nursing is an emerging field. After China's Sichuan earthquake, a pioneer study in Hong Kong provided an educational disaster nursing training to university nursing students [5]. It was found that after two weeks (60 h) of training program the program was able to provide students with disaster nursing-related knowledge. The program also increased students' willingness to participate in disaster nursing programs, and their willingness to continue to further their disaster nursing-related knowledge. Alima, Kawabata, and Nakazawa (2015) conducted research that focused on students receiving disaster nursing training (n = 40). Their participants indicated that training could increase knowledge and skills related to disaster preparedness [6]. The literature also pointed out that after receiving a disaster nursing course, most students would be more prepared for disasters [7], more willing to learn about disaster nursing through continued education [8], and more willing to participate in disaster nursing programs [9]. The discussions of these aforementioned studies focus on students' level of knowledge and their willingness to participate in disaster nursing programs. The aforementioned studies, however, do not discuss the students' behavioral changes after their training, nor the ways in which their behavioral changes impact the society or organizations.

In the past few years, Taiwan has been affected by serious natural disasters. Disaster nursing educational programs have begun to develop there. We can use learning effectiveness to reflect the results of the students' learning to create a student-centered curriculum. There are a number of models that evaluate learning effectiveness. In recent years, the Kirkpatrick model has become one of the evaluation methods of learning effectiveness of medical education programs [10]. After the Kirkpatrick evaluation model was published in the *Journal of the American Society of Training Directors* (ASTD, now known as the *Association for Talent Development*, or ATD) between September of 1959 and February of 1960, this model began to be used to assess the effectiveness of the various training aspects, and the model became widely used to evaluate the effectiveness of many curricula in many educational programs [11]. The model evaluates the effectiveness in four aspects, and the methods as well as the content for assessment are different for each of the four aspects. The first aspect of evaluation focuses on a student's "reaction", i.e., a student's level of satisfaction with regard to the speakers, curriculum, teaching activities, and learning environment and equipment. The second aspect of evaluation focuses on a student's "learning", i.e., the increase of student's knowledge and skills, and the changes in a student's attitude. The third aspect of evaluation focuses on a student's "behavior", i.e., the degree to which a student has applied the acquired knowledge in their daily life and/or workplace. The fourth aspect of evaluation focuses on a student's "results", i.e., a student's ability to improve future work efficiency after their training [12]. Kirkpatrick's evaluation model is different from traditional assessment models. Using the Kirkpatrick evaluation model, each of the results from the lower-levels of evaluation impact the results from the higher-levels of evaluations. The Kirkpatrick evaluation model is characterized by its emphasis on the student's development of skills and transformation of knowledge after their training, the student's application of these skills, and the student's impact on society and/or organizations. In other words, students' learning reaction will affect the learning process, the students' learning process will affect their behavior, and the students' behavioral change will affect his/her achievements as well as the group's achievements [13]. That Kirkpatrick's evaluation model is flexible and can be used to evaluate the learning effectiveness of different types of curriculum [11], and that it suits the characteristics of learning from simple courses to complex ones, this type of model that evaluates various aspects can be based on the student's post-learning performance, their participation in different activities, their experience with the courses, their changes in knowledge and attitude, and their applications of acquired knowledge to their daily lives or the impact on their immediate environments [14].

Most current research on disaster nursing-related curriculum focuses on hospitals or the learning effectiveness of nurses who received disaster nursing-related training [9, 15–18]. Research has rarely focused on the disaster nursing-related curriculum used in schools or on nursing students as a way to explore learning outcomes. Therefore, the purpose of this study is to design disaster nursing curriculum for university nursing students. Through diversified teachings, and by utilizing the four aspects of evaluation from Kirkpatrick's effectiveness evaluation model, we intend to explore the implications of learning effectiveness to find out whether the contents of the curriculum meet the predefined educational goals. Our results can hopefully be used as a reference for future course improvements.

2 Methods

2.1 Participants

Of the senior class in the university's nursing program, there were 70 fourth-year nursing students who participated in disaster nursing courses.

2.2 Course Description

This course was designed based on the International Council of Nurses (ICN) framework of disaster nursing competencies and Emergency Operations Center training programs. We had invited one Chief Operator for the Emergency Operations Center, one Emergency Medical Technician-Paramedic (EMT-P), one nursing education expert specializing in acute and critical nursing from the university's department of nursing, and one nursing education expert specializing in community health to focus on creating a curriculum that included the basic knowledge necessary to students of disaster nursing. The course curriculum (refer to Appendix I) included triage in disaster, sharing of experiences in emergency medical care in disaster-relief, physiological considerations for air-rescues, disaster prevention education, management of dead bodies after disasters and public health, and personal protective equipment of stage C and D. The course required a total of 34 h to complete, which was taught over a period of 18 weeks.

2.3 Teaching Strategies

The applied teaching methods are diverse and include lectures, team teaching, interactive discussions, team-based collaborative learning, case reviews and analyses, and demonstration-performances (refer to Appendix II).

2.4 Research Process

In this study, Kirkpatrick's evaluation model (level 1: reaction, level 2: learning, level 3: behavior, and level 4: results) was the basis for evaluating the students' learning effectiveness.

I. Evaluation of Student Reaction: We assessed the students' reaction towards the disaster nursing training course using an evaluation of the students' level of satisfaction with regard to the course's teaching timetable, content, lecturers, and teaching strategies. We used the 5-point Likert Scale (5: Very Satisfied, 4: Satisfied, 3: Neutral, 2: Dissatisfied, 1: Very Dissatisfied). Opinions and feedback were open-ended and gathered in the form of qualitative descriptions.

II. Evaluation of Student Learning: Using pre-training and post-training tests, we assessed whether the students' disaster nursing-related knowledge increased during the training course. We used a compilation of common public misconceptions regarding natural disasters based on documents published by the World Health Organization (WHO) and other publishers to create the test. The test consisted of 14 questions. The questions were all true or false. The tests were scored on a numerical scale with 0 being the lowest possible score and 14 being the highest possible.

III. Evaluation of Student Behavior: We used the 5-point Likert Scale (5: Strongly Agree, 4: Agree, 3: Neutral/Neither Agree Nor Disagree, 2: Disagree, 1: Strongly Disagree) to determine the likelihood of students' applying their newly acquired knowledge regarding disaster prevention and disaster nursing in their daily lives. The higher the score, the more likely a student would apply their newly acquired knowledge in their daily lives. There were ten questions in total. The highest possible score was 50 and the lowest possible score was 10.

IV. Evaluation of Student Results: We used the 5-point Likert Scale (5: Strongly Agree, 4: Agree, 3: Neutral/Neither Agree Nor Disagree, 2: Disagree, 1: Strongly Disagree) to evaluate the degree to which students, prior to graduation, would use their newly acquired knowledge regarding disaster prevention and disaster nursing in their workplace. The higher the score, the more likely it was that the student would use the newly acquired knowledge in their workplace. There were four questions in total. The highest possible score was 20 and the lowest possible score was 4. The students provided answers to the aforementioned evaluations anonymously.

2.5 Statistical Analysis

The aforementioned evaluations and training feedback forms had a high level of internal consistency (Cronbach's alpha value = .87). SPSS Statistics 23.0 was used to analyze the data. Descriptive statistics, Pearson's correlation coefficient, t-test, multiple regression analysis and other methods were used to understand the student's learning effectiveness.

3 Results and Discussion

Please be sure to refer to Table 1 for an analysis of the basic attributes of the 70 nursing students who participated in this study. The average age of our participants was 21.27 ± 0.51 years. Female were in the majority (91.4%), of which 75.7% have registered nurse licenses. The majority of students (65.7%) had previously received Basic Life Support (BLS) training. The students that had received other specialized training were in the minority: 28.6% of the students received internship experience at an emergency room (ER); 34.3% of the students received Advanced Cardiovascular Life Support (ACLS) training; 14.3% received Emergency Medical Technician-Basic (EMT-1) training.

Table 1. Demographic characteristics of nursing students (n = 70)

Variables		n	%
Mean age (SD)	21.27(± .51)		
Gender	Male	6	8.6
	Female	64	91.4
RN license	Yes	53	75.7
	No	17	24.3
ER internship experiences	Yes	20	28.6
	No	50	71.4
ACLS traning	Yes	24	34.3
	No	46	65.7
BLS traning	Yes	46	65.7
	No	24	34.3
EMT-1 traning	Yes	10	14.3
	No	60	85.7

This study used Kirkpatrick's four-level model to evaluate the students' reaction, learning, behavior, and results. With respect to the first level, which measured students' reactions towards the training program, we found that students were very satisfied. When asked to evaluate their individual levels of satisfaction, with regard to training and teaching strategies, the students on average evaluated their satisfaction levels at 4.43 ± .50 and 4.48 ± .49, respectively (5-point Likert Scale: 5: Very Satisfied, 1: Very Dissatisfied). There was an apparent positive correlation between students' level of satisfaction with the program and their level of satisfaction with the teaching strategies ($r = .70$, $p < .01$; Table 2). The second level of assessment evaluated students' learning. This level of assessment focused on the students' understanding of disaster-relief knowledge before and after receiving the relevant training. The results showed that post-training test scores were higher (average pre-training test score:

4.79 ± 2.06; average post-training test score: 6.96 ± 2.68; $t = 6.234$, $p < .01$). The third level of assessment evaluated students' behavior. This level of assessment focused on the degree to which students would, in the future, apply their acquired knowledge in their daily lives. The average score for acquired knowledge application was 4.22 ± .79 (5: Strongly Agree, 1: Strongly Disagree). The fourth level of assessment evaluated students' results. This level of assessment focused on the students' application of their acquired knowledge in their workplace after they had received disaster nursing training. The average score for acquired knowledge application in the workplace was 4.28 ± .56. After taking the course, most students expressed a willingness to participate in real disaster nursing projects, and there was an apparent correlation between level 4 and level 3 assessments ($r = .45$, $p < .01$; Table 2).

Table 2. Pearson correlation analysis of disaster nursing trainings (i.e. reaction, learning, behavior, results)

	1	2	3	4	5	6
1. Cognition	1					
2. Learning satisfaction	.057	1				
3. Teaching strategies	−.131	.703**	1			
4. Apply knowledge to daily life	.093	.178	.001	1		
5. Apply knowledge on the workplace	.132	.231	.187	.449**	1	
6. total score of knowledge application	.121	.286	.092	.933**	.633**	1

*$p < .05$; **$p < .01$

This study also used multiple regression analysis to explore whether there was a correlation between effective disaster nursing knowledge, learning satisfaction and teaching strategies, and students' application of their acquired knowledge in their daily lives or in their workplaces. Step 1 in Table 3 showed that these three variables (effective disaster nursing knowledge, learning satisfaction, and teaching strategies) can be used to predict the trends regarding whether overall acquired knowledge will be applied by the students ($R^2 = .109$, $F = 2.702$, $p = .053$). Moreover, students' level of satisfaction with the training can be used to judge whether they are more likely to apply their acquired disaster nursing knowledge ($t = 2.475$, $p = .016$). However, teaching strategies and effective disaster nursing knowledge were not shown to be correlated with the students' overall application of acquired knowledge. Step 2 in Table 3 considers the students' professional qualifications and experiences as independent variables (i.e. internship experience in an ER, qualification as a registered nurse, basic life support training, advanced cardiovascular life support training, and emergency medical technician-basic training). The results showed that these independent variables significantly increased the students' likeliness of applying overall acquired knowledge in settings outside of the classroom ($R^2 = .231$, $F = 2.249$, $p = .036$). When these findings were compared with the findings from the first set of variables considered (in Step 1) we can see that learning satisfaction levels still have significant predictability traits ($t = 2.757$, $p = .008$). In addition, students who have received BLS training can be predicted to be more likely to apply their acquired disaster nursing knowledge ($t = 2.155$, $p = .035$) in settings outside of the classroom. From our analysis of Table 3, we learned that the statistical relationship between students' application of acquired knowledge and their learning satisfaction with the course cannot be simplified to a direct relationship, but rather it was influenced by the students' professional qualifications and experiences.

Table 3. Summary of multiple regression analyses for predicting students' application of acquired knowledge after having received disaster nursing training

	Variables	b	β	t	F	R^2
Step 1	Cognition	0.179	0.075	0.629	2.702[#]	0.109
	Learning satisfaction	0.640	0.410	2.475*		
	Teaching strategies	−0.401	−0.183	−1.96		
	Constant	46.361				
Step 2	Cognition	0.097	0.041	0.330	2.249*	0.231
	Learning satisfaction	0.747	0.475	2.757**		
	Teaching strategies	−0.588	−0.270	−1.587		
	ER experience	−1.971	−0.141	−1.111		
	RN license	1.676	0.114	0.908		
	ACLS training	−0.125	−0.009	−0.076		
	EMT-1 training	2.172	0.121	0.975		
	BLS training	3.301	0.248	2.155*		
	Constant	41.271				

$p = .053$; *$p < .05$; ** $p < .01$

Learning satisfaction can be used to predict a student's likeliness to apply acquired knowledge outside of the classroom. Thus, we decided to analyze whether a student's professional qualifications affected his/her learning satisfaction. We considered learning satisfaction as a dependent variable and we considered the student's professional qualifications (i.e. internship experience in an ER, qualification as a licensed nurse, basic life support training, advanced cardiovascular life support training, emergency medical technician-basic training, etc.) as independent variables. The results of this analysis showed that a student's professional qualifications did not affect his/her satisfaction with the training (Table 4).

Table 4. Summary of regression analysis predicting learning satisfaction

Variables	b	β	t	F	R^2
ER experience	−1.847	−0.207	−1.675	1.918	0.130
RN license	−1.195	−0.127	−1.021		
ACLS training	−0.206	−0.024	−0.192		
EMT-1 training	1.635	0.142	1.135		
BLS training	−0.863	−0.101	−.858		
Constant	38.487				

4 Conclusions

Within the framework of the Kirkpatrick's four-level training evaluation model, the overall average score for the training program exceeded four points on each level of assessment. These results provide evidence of the training course's value as well as the students' learning effectiveness. The results can be used to better design curriculum and pedagogical strategies that suit the needs of students, and be used to propose the implementation of disaster nursing-related courses and teaching methods. This study can be used to create disaster nursing courses that suit the conditions of the nation, and can also be used as a reference for designing related courses in nursing schools in the future. This study also found that a student's learning satisfaction and his/her having attended a BLS training will clearly affect his/her likeliness to apply newly acquired disaster nursing knowledge. In order to improve the effective study and applications of disaster nursing, special attention should be paid to the students' learning satisfaction levels. Before taking disaster nursing training courses, students should be advised to take a BLS training course.

Appendix I

Course Content and Schedule for Disaster Nursing

	Units	Teaching strategies	Hours
1	Triage in disaster, apply START system in disaster and introduction EOC	Audiovisual, Case review and analysis	3
2	Recognition of ICS	Lectures, Case review, and analysis	1
3	Air-Rescue of Physiological consideration	Team teaching	2
4	Disaster Prevention Education	Out-school and experiential-learning	4
5	Experience of first aid in disaster-role of EMT-P	Demonstration-performance	2
6	Humanitarian Assistance in Disaster	Team teaching	2
7	Concept of trauma nursing	Interactive discussion	4
8	Experience of disaster relief medical aid in Union of Myanmar - role of nurses	Team teaching	2
9	Video-Surviving Disaster	Audiovisual, Group discussion	2
10	Management of dead bodies after disasters	Lectures, Interactive discussion	2
11	Public health impact of disasters-oral present	Team-based collaborative learning	2
12	Practicing Personal Protective Equipment of stage C and D	Demonstration/performance	2
13	Posttraumatic Stress Disorder in disaster-oral present	Team-based collaborative learning	2

(*continued*)

(*continued*)

	Units	Teaching strategies	Hours
14	Disaster management: the stress and adaptive of health workers in disaster - oral present	Team-based collaborative learning	2
15	Outdoor learning experience sharing	Group discussion	1
16	Couse evaluation	Group discussion	1

Appendix II

Team teaching

Demonstration/ performance

Outdoor learning and experiential- learning

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Educational Needs in Neurological Rehabilitation – "Brain4Train" Survey Outcomes from European Countries

Joanna Bartnicka[1(✉)], Cristina Herrera[2], Raquel Portilla[2], Agnieszka Zietkiewicz[1], Katarzyna Mleczko[1], Esteban Pavan[3], Enrique Varela Donoso[4], and David Garrido[2]

[1] Institute of Production Engineering, Silesian University of Technology, Gliwice, Poland
{Joanna.Bartnicka,Agnieszka.Zietkiewicz, Katarzyna.Mleczko}@polsl.pl

[2] Instituto de Biomecánica de Valencia, Valencia, Spain
{cristina.herrera,raquel.portilla,david.garrido}@ibv.upv.es

[3] Fondazione Politecnico di Milano, Milan, Italy
esteban.pavan@polimi.it

[4] European Society of Physical and Rehabilitation Medicine, Rotterdam, Netherlands
evarelah@enf.ucm.es

Abstract. The aim of this paper is to present the first outcomes of an international project titled "Development of innovative Training contents based on the applicability of Virtual Reality in the field of Stroke Rehabilitation". Particularly two aspects were described: (1) recognition of educational needs of medics who support neurological patients in their rehabilitation process, (2) the concept of structure and contents of an e-learning course about this topic.

The methodology was based on a questionnaire that was spread among professionals within European countries and, then, on focus group panels deepening selected results obtained in the survey. The questionnaire included 7 categories and 24 questions in total, covering the key training needs in as the field of using virtual reality tools and biomechanical technologies in post-stroke rehabilitation. The major findings of the research allowed describing the subjects of four training modules and learning sessions that were the groundwork for preparing cross-sectional matrix of competencies, skills and knowledge for innovative technology-based post-stroke rehabilitation.

Keywords: International survey · Online course · Post-stroke rehabilitation Virtual Reality · Biomechanical systems · Brain4train

1 Introduction

Neurological rehabilitation covers a wide spectrum of diseases, trauma, or disorders of the nervous system. A group of neurological diseases that are especially disabling, and a growing concern for rehabilitation providers, is composed by the different forms of stroke, also known as cerebrovascular accident (CVA). The World Health Organization (WHO) estimates the yearly global average incidence of stroke in approximately 15

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million people, of which 5 million people die and another 5 million become chronically disabled [1]. After stroke, people suffer from behavioral deficits in both cognitive and motor domains [2] relying on family members for on-going support [3].

An important approach for reducing mortality in post-stroke patients, and severity of stroke consequences, consists of a specific stroke rehabilitation pathway. It is defined as any treatment or exercise performed with the aims of encouraging early body mobilization, facilitating not only neurologic recovery, but also achieving functional recovery and minimizing daily disability [4]. Stroke rehabilitation aims, in consequence, to improve the functions and well-being of the post-stroke patients. In order to obtain the best possible results from the rehabilitation process, this should start as soon as possible after CVA and should be so intense in terms of time and diversity as possible. However, reports of inadequate understanding of rehabilitation techniques are common [3]. Additionally, the number of existing rehabilitation structures with the possibility to complete the recovery of post-stroke patients after they leave the hospital, is limited, and costs of this rehabilitation care are most often supported by patients themselves [5]. Self-rehabilitation methods, as a supplementary rehabilitation to conventional clinically-supported methods, are thus necessary to face growing rehabilitation needs [6] and become a key point in restoring the patients to professional and social activities, especially in the face of financial, organizational and structural problems, in most cases regardless of the country in which they live. Moreover, the experiences show that self-rehabilitation is feasible [5] and a promising approach that could become a standard procedure in stroke rehabilitation.

On the other hand, inclusion of self-rehabilitation into the patients' treatment requires a properly managed knowledge-shared campaign and, above all, professional preparation of medical staff to implement this alternative form of rehabilitation into practice. In effect, the most important aspects of this approach are, firstly, that the rehabilitation program is individually tailored to the patient [7] and he/she has the opportunity to receive the self-rehabilitation program that is developed according to their health needs.

Rehabilitation technologies to improve functional recovery, including robotics, biomechanical tools, are continuously growing. Among a number of promising technological innovations, some evidence shows that Virtual Reality tools have the capacity to enhance rehabilitation of post-stroke people, which has to be repetitive, task-specific and intensive for neuroplasticity to occur.

A preliminary analysis of the treatment procedures followed in different countries of Europe, concluded that both self-rehabilitation methods and the use of technologies like Virtual-Reality in rehabilitation, are still new, and that these subjects are not included in any medicine curriculum program.

Starting from this background, it was formulated the concept of the international Erasmus + project titled "Development of Innovative Training Contents Based on the Applicability of Virtual Reality in the Field of Stroke Rehabilitation – Brain4Train", which aims to develop an e-learning tool, available in 4 languages (English, Spanish, Polish and Italian), in order to provide up-to-date knowledge on techno-innovative recovery scenarios to the health professionals involved in the rehabilitation process of patients after stroke.

2 Materials and Methods

Virtual reality (VR) systems, able to recreate a controlled enriched environment, offer several features in neurological rehabilitation, such as the possibility of repeating goal-oriented tasks, while promoting patient learning and motivation. The main advantage of Virtual Reality, over traditional forms of rehabilitation, is the possibility to show the proper way of carrying out activities, including unusual activities, and their results. The later one is usually impossible at real conditions, like real work place [8, 9]. What is also important, self-training materials based on VR might be easily distributed and used as many times as necessary.

But questions arise about the knowledge for using VR-based tools and whether health professionals involved in post-stroke rehabilitation are ready for using such innovative, technological facilities or it could be necessary to gain new skills in order to properly transfer VR-based tools and self-rehabilitation into practice. In the project framework, a survey was carried out among medical professionals across Europe, in order to identify their current background and possible educational needs in the field of Virtual Reality and biomechanical technologies that could support rehabilitation of post-stroke patients. In particular, a questionnaire was developed with the objective of gathering valuable feedback that helps in defining and matching training contents and features to the actual expectations manifested by rehabilitation practitioners:

Question 1: what kind of specialists, a training about the use of Virtual Reality and biomechanical technologies in supporting post-stroke patients' treatment, should be directed to?
Question 2: what is the actual knowledge about Virtual Reality and biomechanical technologies among professionals involved in post-stroke patients' treatment?
Question 3: what is the expectation regarding the subject of training content?
Question 4: what is the expectation about organizational aspects of training content?

The questionnaire was translated into three languages: English, Polish and Italian, and distributed in two ways:

- Online – the questionnaire was implemented into SurveyMonkey and EUSurvey online–platforms, and the links have been sent to the potential respondents, most of them directly invited by the European Society of Physical and Rehabilitation Medicine;
- Traditional – a paper version of the questionnaire was distributed among healthcare professionals working in hospitals, with the consent of the hospital management.

The questionnaire answers collected from the two methods were processed in MS Excel spreadsheet to generate descriptive statistics that quantitatively summarize the responses.

The questionnaire included 7 categories and 24 questions in total covering the issues included into the above formulated questions. Particularly the categories represent the following fields:

1. Demographic data;
2. Experience in stroke accident treatment;

3. Stroke treatment recognition;
4. Stroke self-rehabilitation knowledge;
5. Course features;
6. Training – experience;
7. Training needs for future.

In order to clarify training content and features, three focus groups were also organized. Each focus group was composed of specialists in neurological rehabilitation representing Spanish, Polish and Italian professionals.

Both the research surveys and the focus groups were carried out from November 2017 to March 2018.

3 Results

A total of 227 responses were gathered from 34 different countries, mainly located in Europe. In the Fig. 1, the distribution of respondents by country is presented.

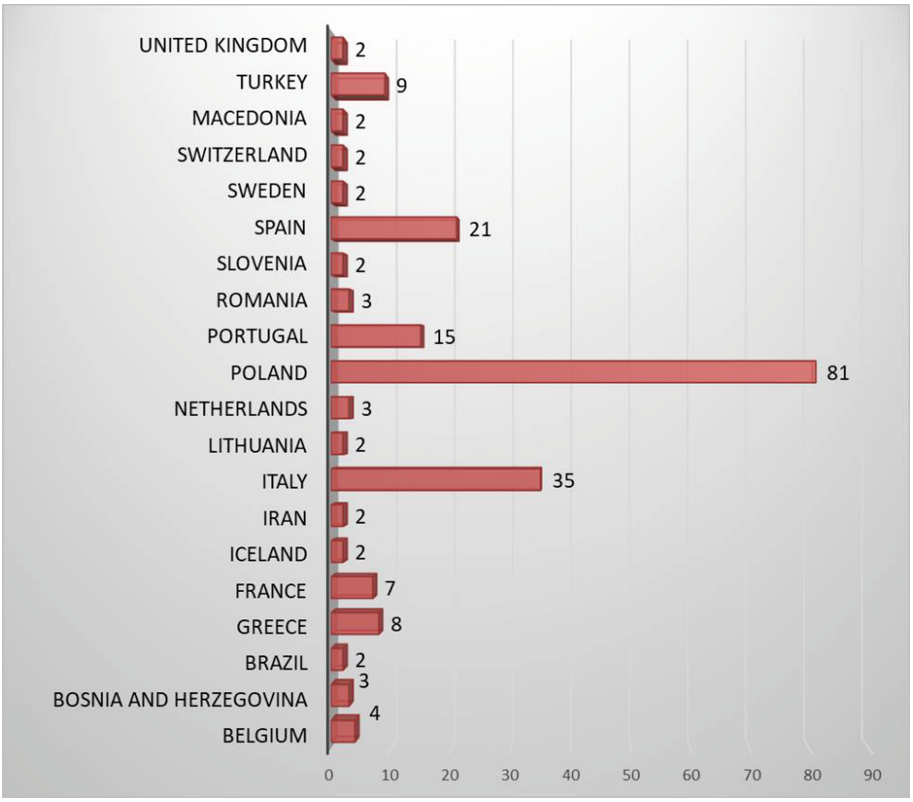

Fig. 1. The distribution of respondents by country

As can be seen, 81 respondents (36%) of the sample were from Poland, followed by Italy, 35 respondents (15%), Spain, 21 respondents (9%) and Portugal 15 respondents (7%). The rest of the countries was represented by less than 10 people: apart from those included in the chart, there were also individual representatives of Croatia, Australia, Egypt, Israel, Russia, Iraq, Honduras among others.

The vast majority of the respondents were women, see Fig. 2, 59% of the professionals, all involved in post-stroke rehabilitation.

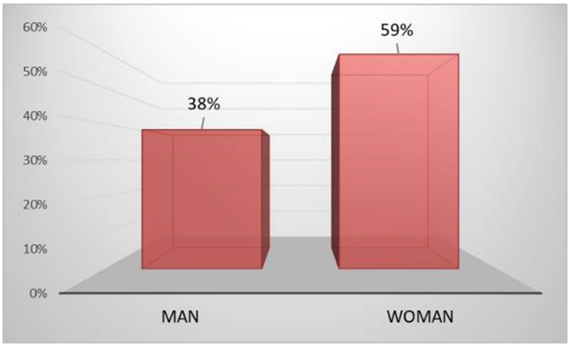

Fig. 2. Gender distribution of respondents

Regarding the age of survey participants, see Fig. 3, most of the respondents were aged between 25 and 45 years (55% of the sample), but there was also a high percentage of aged, expert professionals.

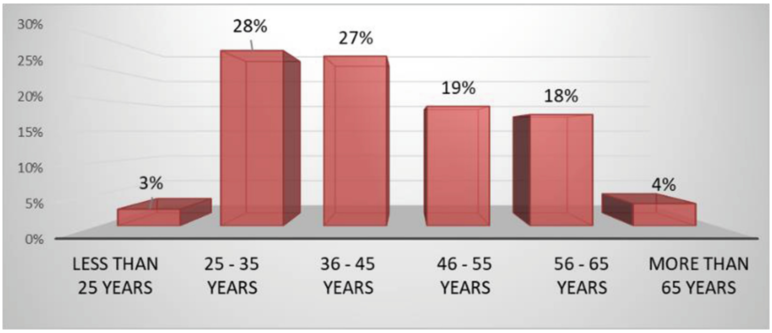

Fig. 3. Age distribution of respondents

The reliability of the survey outcomes and, consequently, the identification of training needs that would be necessary to improve post-stroke rehabilitation, strongly depends on the respondents' expertise in this field. In the Fig. 4, it is presented the distribution of respondents according to their professional experience in rehabilitating stroke patients. The most experienced group of respondents, i.e. from 16 to more than 20 years of practice, was represented by 32% of the professionals, and 20% of them have treated more than 500 post-stroke patients per year. These numbers give greater validity to the sample.

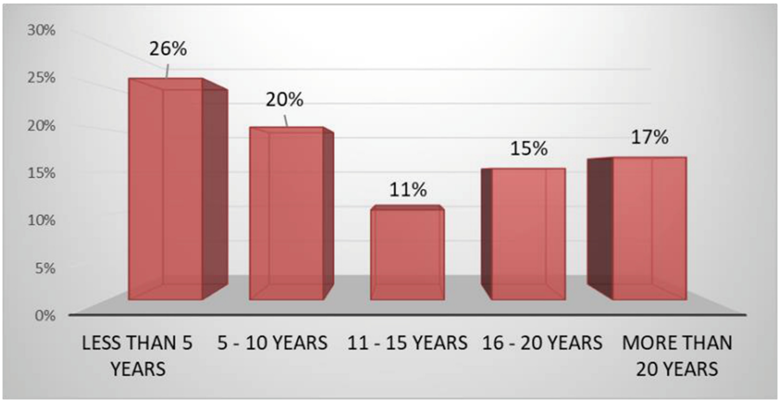

Fig. 4. Years of respondents' experience

The survey outcomes reflect the multidisciplinary aspect of stroke survivors' rehabilitation: most of the respondents (65%) were specialized in rehabilitation (physiatrist), followed by physicians and neurologists (nearly 10% each) (Fig. 5).

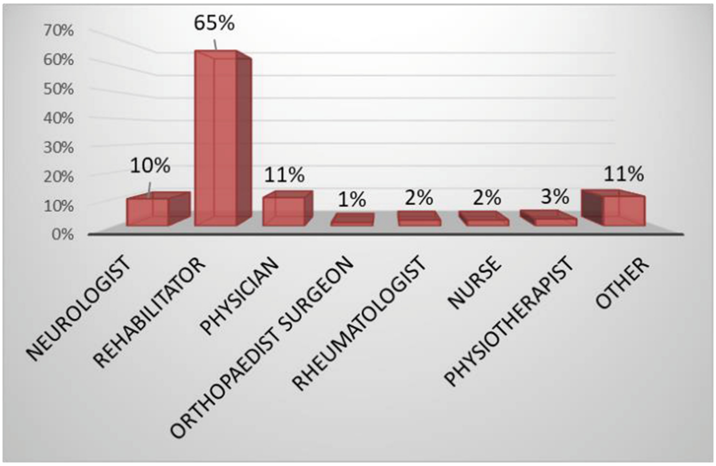

Fig. 5. Medical specialization of the respondents

Post-stroke patients with chronic, moderate impairment could take advantage from supervised, home-based therapy. This was confirmed by most of the professionals (67%), which claimed that patients' rehabilitation should take place in both specialized healthcare institutions and at home (Fig. 6). For 12% of the respondents, mainly rehabilitators and physiotherapists, it is essential that rehabilitation is also performed at home, in addition to the ambulatory rehabilitation. This outcome confirmed the importance of providing self-rehabilitation guidelines, e.g. those based on online training, to support, from one side, the medical staff and, from the other side, the patients and their family.

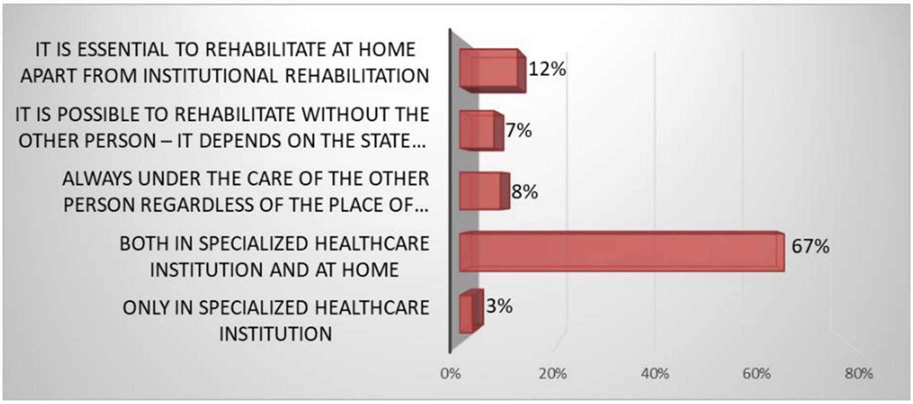

Fig. 6. Opinion about the setting where patient's rehabilitation should take place

Although the importance of defining guidelines to correctly perform a home-based rehabilitation, almost one third of respondents do not know any kind of instruction guidelines for self-rehabilitation of post-stroke patients (Fig. 7) and do not know where or how they could obtain one the available guidelines.

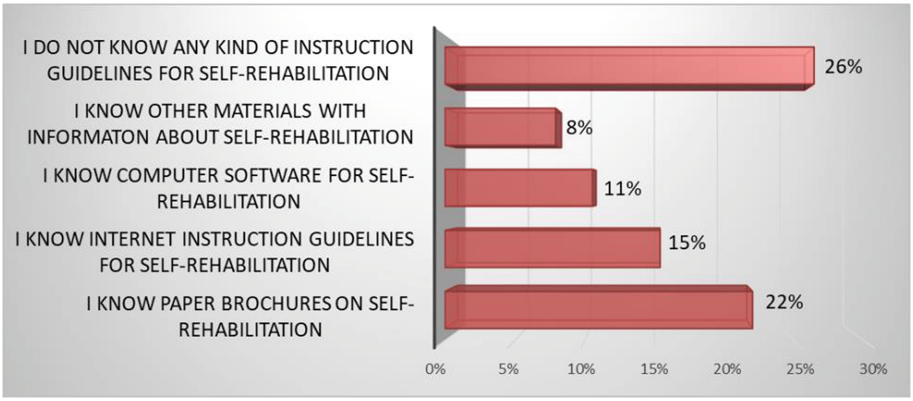

Fig. 7. Responses about the knowledge of self-rehabilitation guidelines

Even if the medical professionals know some guideline for self-rehabilitation, or have opportunity to obtain one, only 18% of them actually use these materials in practice. Some respondents (25%) claimed that they give some instructions to the patients, if they consider this is necessary, while other respondents never gave any instruction to their patients (25%).

Regarding respondents' instruction and, in particular, any training previously done about the use of Virtual Reality tools and biomechanical technologies in self-rehabilitation process, the major part of the respondents have not taken part in any training in the last two years or never (Fig. 8).

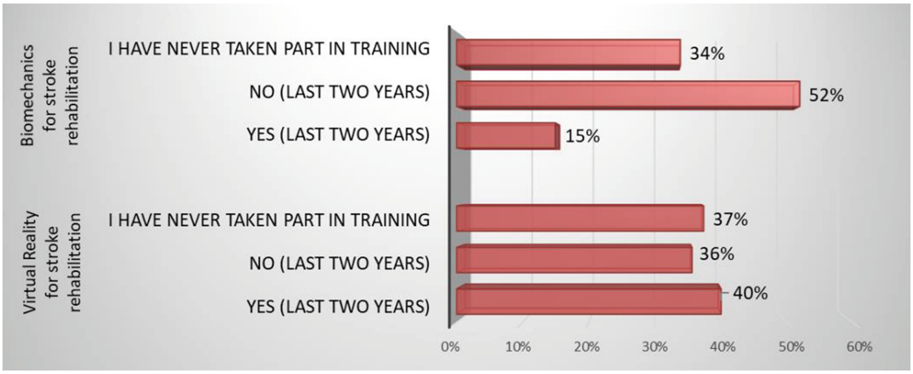

Fig. 8. Training experience regarding Virtual Reality and Biomechanics technologies in stroke-rehabilitation

Because no courses on self-rehabilitation are part of the obligatory medical educational curriculum, and due to limited time available for continuous professional training, we assumed that implementing appropriate up-to-date knowledge into training content, as well as a professional-friendly course, could be the key points to encourage medical staff to join a training program to improve their skills. According to respondents' opinion, online courses seem to be the appropriate learning form in this sense. The more that it is increasingly popular in the healthcare field [10]. This opinion corresponds with respondents' expectation: the vast majority of them (55%) claimed that an e-learning

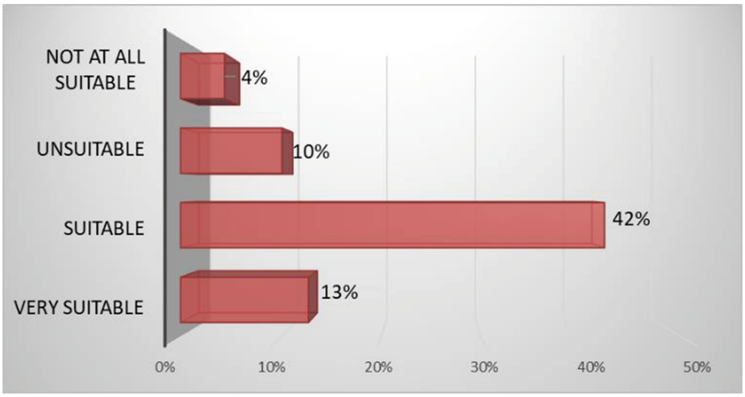

Fig. 9. The respondents opinion about appropriateness of online training

course could be suitable or very suitable for professional training. Only 14% of them have opposite opinions (Fig. 9).

At the same time, the international group of respondents agreed that an on-line training course should last between 20 and 50 h (30%, see Fig. 10), or less than 20 h (23%), though 10% of respondents said that more than 50 h would be more appropriate.

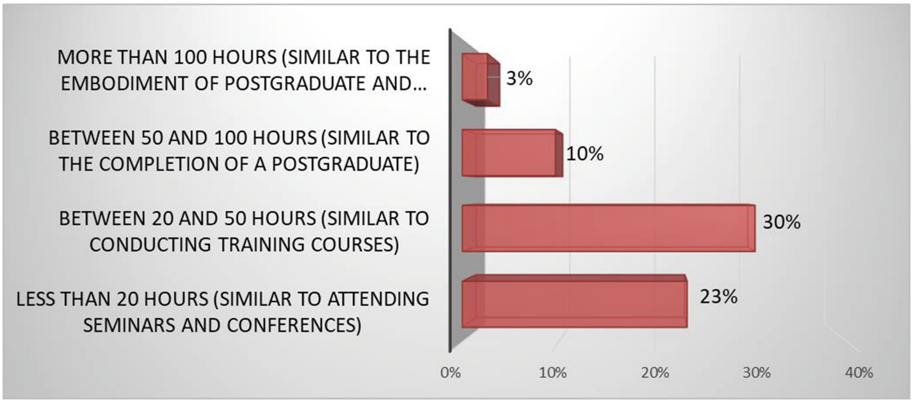

Fig. 10. The preferred duration of e-learning course according to respondents' opinion

In reference to survey results about specific subjects of training, the focus group sessions' outcomes allowed to develop a general backbone of training content that represents all important approaches to the self-rehabilitation of post-stroke patients based on new technologies like Virtual-Reality or biomechanical technologies. The course content should include the following main areas:

– Clinical features, impairment and functional evaluation of stroke.
– Practice guidelines for stroke rehabilitation.
– New technologies in rehabilitation: Virtual Reality and biomechanics – descriptions, usefulness, procedures, examples.
– Case studies of using Virtual Reality and biomechanics technologies in stroke-rehabilitation.

Each of these areas is divided into training modules and sessions that aim to provide medical professionals useful knowledge and skills of how to support post-stroke rehabilitation with the currently available technological instruments.

According to focus groups' opinion, the training material should be prepared in such a way that it will be concentrated on clinical-practical aspects of the use of the new technological instruments in the stroke rehabilitation like planning a rehabilitation process or the selection of the most appropriate tool for each patient. Finally, according to the health professionals' opinion, the training course should be useful for the job and for gaining new professional skills, as well as to retrain professionally through the use of new techniques; all expectations that translates into better serving the post-stroke patients.

4 Discussion

According to the questionnaire respondents, it can be concluded that the need and willingness regarding post-stroke patients' rehabilitation improvement is high among professionals from all European countries. A clear numerical predominance of women taking part in the survey reflects the fact that women are mostly involved in the rehabilitation process of post-stroke patient, but also that the rehabilitator profession is more popular among women than man. This information could be used within the preparation of training materials that should contain most effective methods based on cognitive abilities of men and women [11].

According to the information gathered from surveys, the groups of rehabilitators and physiotherapists are the most interested in the proposed topics and, consequently, potential end users of the training course. According to their opinion, self-rehabilitation is essential for patients' recovery because of the continuity of the rehabilitation process. An opposite opinion was expressed by some doctors specialists, like neurologists, for whom the subject and form of training course is considered to be unsuitable because, according to their opinion, stroke rehabilitation cannot be done independently by the patient. These different opinions reflect the treatment burden differences among these professionals. Rehabilitators and physiotherapists approach patient's treatment as something more than medical procedures and find it important to plan recovery on the basis of daily life and social integration of patients. In the same time, they recognize the relationships between self-rehabilitation, positive financial aspect and higher degree of efficiency of treatment supported by new technologies, that can be carried out at home.

Despite the fact that rehabilitators find self-rehabilitation a very important point in the whole process of recovery, they generally do not use dedicated guidelines or instructions in their clinical practice. Possibly, it results from the lack of specialized trainings that are available on the healthcare training offer.

The development of an on-line course about self-rehabilitation, available in different languages, which would be open for all health professionals should meet the expectations of both rehabilitators or physiotherapists, which are mainly involved in the post-stroke patients' rehabilitation.

Some of the survey respondents were not convinced about the adequacy of online form for a course in these topics. It is probably connected with the necessity of learning practical skills, what is more challenging without workshop classes. Vast majority of the respondents highlighted that training contents must be focused on practice, in order to effectively increase the skills and be useful for the job.

On the other hand, and taking into account the preferences expressed by the experts, the possibility of taking advantage of information technologies, like computer simulations, video lessons, interactive games, can provide the new ways of including also practical aspects into e-learning process.

5 Conclusions

The research findings obtained from surveys and focus group sessions, provide the opportunity for developing a universal and international e-learning course on using innovative solutions, like Virtual Reality and biomechanics technologies, in the rehabilitation process of post-stroke patients. In particular, the study outcomes made it possible to recognize the knowledge gaps within the international professionals taking part in stroke patients' recovery and hence to complete formative e-learning content according to real medical professionals' needs. The results showed that e-learning technique is generally preferable or accepted.

Particularly, the study allowed us to know the target groups' opinions about the following questions:

Question 1: what kind of specialists a training about the use of Virtual Reality and biomechanical technologies in supporting post-stroke patients' treatment should be directed to?
Answer 1: training on innovative technologies like Virtual Reality and biomechanics systems are especially expected by rehabilitators and physiotherapists, who probably better understand the need for continuity of post-stroke rehabilitation. In opposite to several neurologists' opinion, they consider self-rehabilitation to be an inseparable part of the recovery process of these patients. The reason of so different opinions could be a closer, more personal relationship with the patients, making their needs more visible.
Question 2: what is the actual knowledge about Virtual Reality and biomechanical technologies among professionals involved in post-stroke patients' treatment?
Answer 2: only one fifth of the people surveyed consider their knowledge level is sufficient to be able to use them in clinical practice. The research outcomes prove that there is the need for providing more accessible and useful knowledge to make the rehabilitation process more effective.
Question 3: what are the expectations regarding the subjects of training content?
Answer 3: Particularly, knowledge of Virtual Reality tools and biomechanical technologies should be useful for developing personalized rehabilitation plans for both functional improvement of post-stroke patient and functional evaluation of rehabilitation progress. The training contents should be focused on higher function training like e.g. apraxia and should be developed based on scientific evidence. Also, the attention to patient's family and family care was considered another important aspect in stroke rehabilitation but many times neglected by people involved in rehabilitation process.
Question 4: what is the expectation about organizational aspects of training content?
Answer 4: online training course is considered to be the most appropriate way to share knowledge of new technologies in stroke rehabilitation. This form of training course and the multilingualism of the training materials, make it possible to let the course be available for wide audience around the world. Because of time limitation of medical practitioners, the preferred duration of training course was that it should last up to a

maximum of 100 h. The training materials should be concise, accurate and include more audiovisual knowledge representation.

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A Study of Nursing Competence for Nursing Graduates Among Different Vocational Education Programs

Yu-Ching Tu(✉), Cheng-Chieh Tsai, and Hsiu-Rong Cheng

Department of Nursing, Chung-Hwa University of Medical Technology, Tainan, Taiwan
pochacco2293@yahoo.com.tw

Abstract. This cross-sectional study explored nursing students' professional competency and examined the differences of nursing professional competence among three vocational education programs. Self-administered questionnaires were used to investigate nursing students' professional competency including the ability to take care of patients, communication, teaching, management, research, and self/professional growth dimensions. Participants' mean competency score was 3.50 ± 0.61 (total = 5 points). Professional competency significantly differed among students of different vocational education programs; continue-two-year-program students and four-year-program students were more competent than five-year-program students ($F = 11.165$, $p < .001$). Furthermore, there were significant differences in female students of different vocational education programs with respect to competency; continue-two-year-program students were more competent than five-year-program students ($F = 11.599$, $p < .001$). Professional competency significantly differed in terms of the length of nursing students' vocational education. Evaluating nursing students' competency might be useful as an indicator of nursing education outcomes.

Keywords: Nurse competence · Nursing graduates · Nursing education Vocational education · Patient safety

1 Introduction

Nursing is recognized as a respectable profession worldwide. Competence in nursing has a direct influence on the health and safety of all patients [1]. Most healthcare providers begin their healthcare professional education expecting to acquire the knowledge and skills needed to provide high-quality care [2]. Because of the rapid changes in healthcare delivery, expansion of nursing services, and health needs of various populations, new graduates have difficulty critically thinking in clinical situations [3, 4]. Insufficient competencies in basic patient care are a source of stress for new graduates [5]. Competence is seen as a series of integrated capabilities comprising clusters of knowledge, skills, and attitudes necessary for task performance, problem-solving, and effective functioning in a certain profession, organization, job, role, and situation [6]. In addition, competence includes cognitive, functional, personal, and ethical competences. It relates to an overall job done well as measured against a system

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of minimum standards and demonstrated by performance and outputs [7]. Competence frameworks are generally developed for assessing performance in relation to set standards and developing programs [7].

Professional regulatory bodies have been set up in many countries to establish guidelines for nursing licensure and regulation of practice and education. The Nursing and Midwifery Board of Australia (2006) defines competency standards for registered nurses (RNs) as the combination of skills, knowledge, attitudes, values, and abilities that underpin effective and/or superior performance in a profession/occupational area [8]. The Singapore Nursing Board (SNB, 2012a, 2012b) states that the core competencies set the foundation for RNs to maintain their competence and acquire additional competencies or advanced clinical skills to deliver safe client care in response to changing healthcare needs and advancement in technology [9]. A competency framework is defined as a guideline to facilitate directive changes within the nursing curriculum and includes the six key competencies: culture, ethics, and values; health promotion and prevention, guidance, and teaching; decision-making; communication and teamwork; research, development, and leadership; and nursing care from European Federation of Nurses [10].

Defining the nursing competence of an RN is difficult, as well as there is a lack of consensus. There are various tools for assessing clinical nursing abilities, which vary according to the national standards and the conditions of license issuance [11, 12]. There is an international agreement that nursing competence must be viewed from a holistic perspective [13]. Some studies have focused on newly-graduated nurses; for example, Lofmark et al. [14] summed four factors (communication, patient care, personality characteristics, and knowledge utilization), and Berkow et al. [15] grouped six categories (clinical knowledge, technical skills, critical thinking, communication, professionalism, and management of responsibilities). Black et al. [16] addressed five categories for entry-level RNs: professional responsibility and accountability, knowledge-based practice, ethical practice, service to the public, and self-regulation.

In Taiwan, many changes in health care lead to increased demand with respect to nurses' competence. Taiwan Nursing Accreditation Council (TNAC) has set up eight core competencies for Bachelors of Science in Nursing (BSN) graduates [17]. The Technological and Vocational Education (TVE) system of nursing in Taiwan. Students from five-year junior colleges receive an associate degree upon graduation. Then, they may take the TVE entrance examination for a continue-two-year-program at colleges of technology (accumulated seven years in train). They would receive a bachelor's degree upon graduation. Furthermore, students from senior high school can take the TVE entrance examination to enter the four-year colleges of technology/university of science and technology program and receive a bachelor's degree [18]. The definition of core competence differs in nursing schools; therefore, no coherent tools can be used by accreditation schools. Therefore, a practical comprehensive assessment tool is required for assessing students' learning outcomes. Moreover, the evaluation of competencies achieved from different vocational education programs has not been documented to date.

2 Method

2.1 Design and Sampling

A cross-sectional survey of nursing undergraduates who were in five-year, four-year, and continue-two-year programs was conducted. All participants were full-time nursing students enrolled in their final semester; those without a formal registration in schools or who were not up to graduation standards were excluded. A convenience sample of 365 questionnaires was returned. Data were collected from March–July 2017.

2.2 Measurements

The research tool used was a self-administered questionnaire, which was specifically designed for this study. Based on the eight core competencies for BSN, we had developed competences scale for baccalaureate nursing students, we constructed a learning outcome scale attributes of core competence and psychometric testing. The questionnaires were partly designed based on a literature review [17, 19]. We consulted with five experts regarding face and content validity of the instruments. We also tested the instruments using a sample of 20 nursing students from a previously study. Some minor wording changes were made as per the feedback received from experts and nurses.

Demographic Characteristics. A demographic questionnaire was included in the study to elicit information about the participants' age, sex, education program.

Nursing Competence Scale. The 57-item nursing competence scale is comprised of six dimensions: take care of ability (13 items), communication ability (9 items), research ability (7 items), teaching ability (12 items), management ability (8 items), self/professional growth ability (8 items), which are measured using a five-point Likert scale from five (strongly agree) to one (strongly disagree); a higher scores indicated a more nursing competence. The internal consistency reliability of this scale was high (Cronbach's alpha = 0.96).

2.3 Data Analyses

Statistical analyses were performed using SPSS 21.0 (Armonk, NY: IBM Corp.). The Kolmogorov–Smirnov test revealed that nursing competence scores were normally distributed ($p > .05$). Independent-sample t-tests and one-way analyses of variance were performed to examine mean differences between binary and categorical demographic characteristics, using the Bonferroni comparison procedure. $p < .05$ was considered statistically significant.

3 Results

3.1 Participants

There were 365 participants enrolled in this study. Of the total number of participants, 36.71% were continue-two-year-program students (n = 134), 21.09% were four-year-program students (n = 77), and 42.19% were five-year-program students (n = 154). The mean age of participants was 21.52 (SD = 0.46) years, continue-two-year-program students was 22.15 (SD = 0.32) years, four-year-program students was 22.22 (SD = 0.52) years and five-year-program students was 20.19 (SD = 0.54) years. The majority of the participants were female (n = 344, 94.33%), continue-two-year-program female students were 35.18% (n = 128), four-year- program female students were 18.32% (n = 67), and five-year-program female students were 40.83% (n = 149) (Table 1).

Table 1. Nursing students' demographics (N = 365)

	n [%] Mean (SD)			
	All	Continue-two-year	Four-year	Five-year
Number of people	365	134 [36.71]	77 [21.09]	154 [42.19]
Age	21.52 (0.46)	22.15 (0.32)	22.22 (0.52)	20.19 (0.54)
Gender				
Female	344 [94.33]	128 [35.18]	67 [18.32]	149 [40.83]
Male	21 [5.67]	6 [1.52]	11 [3.10]	4 [1.05]

3.2 Nursing Competence and Its Association with the Three Course Program

Table 2 shows participants' nursing competence as per the three program options. Overall nursing competencies of the participants was 3.50, continue-two-year- program students was 3.65 (SD = 0.60), four-year-program students was 3.54 (SD = 0.60) and five-year-program students was 3.36 (SD = 0.59). Continue-two-year program students and four-year-program students reported a higher level of overall nursing competencies than did five-year-program students ($F = 11.165$, $p < .001$).

The average score of the all participants' six dimensions nursing competencies in order: the ability to communication ability was 3.71 (SD = 0.64), take care of ability was 3.57 (SD = 0.59), the ability to self/professional growth was 3.55 (SD = 0.69), teaching ability was 3.51 (SD = 0.70), management ability was 3.34 (SD = 0.82), research ability was 3.23 (SD = 0.74), respectively.

Continue-two-year program students (3.71 ± 0.58) reported a higher level of take care of ability than did four-year- program students (3.55 ± 0.62) and five-year-program students (3.45 ± 0.57) ($F = 8.737$, $p < .001$). Continue-two-year- and four-year-program students reported a higher level of communication ability ($F = 7.309$, $p < .001$), research ability ($F = 12.528$, $p < .001$), teaching ability ($F = 8.988$, $p < .001$), management ability ($F = 13.512$, $p < .001$), self/professional growth ability ($F = 3.414$, $p = .033$) than did five-year-program students. (Table 2).

Table 2. Comparison on nursing competence among three course programs (N = 365)

	Mean (SD)				*F*	*p*
	All	Continue-two-year[1]	Four-year[2]	Five-year[3]		
Overall	3.50 (0.61)	3.65 (0.60)	3.54 (0.60)	3.36 (0.59)	11.165	<.001 1 > 3 2 > 3
Gender						
Female		3.66 (0.59)	3.47 (0.59)	3.35 (0.58)	11.599	<.001 1 > 3
Male		3.62 (0.77)	3.98 (0.43)	3.66 (0.82)	1.036	.370
t		0.127	−3.122	−1.287		
p		.900	.002	.202		
Take care of ability	3.57 (0.59)	3.71 (0.58)	3.55 (0.62)	3.45 (0.57)	8.737	<.001 1 > 2 1 > 3
Communication ability	3.71 (0.64)	3.85 (0.60)	3.74 (0.61)	3.59 (0.68)	7.309	<.001 1 > 3 2 > 3
Research ability	3.23 (0.74)	3.41 (0.75)	3.32 (0.66)	3.04 (0.73)	12.528	<.001 1 > 3 2 > 3
Teaching ability	3.51 (0.70)	3.66 (0.67)	3.55 (0.67)	3.36 (0.71)	8.988	<.001 1 > 3 2 > 3
Management ability	3.34 (0.82)	3.54 (0.76)	3.45 (0.76)	3.12 (0.84)	13.512	<.001 1 > 3 2 > 3
Self/professional growth	3.55 (0.69)	3.64 (0.70)	3.59 (0.65)	3.45 (0.68)	3.414	.033 1 > 3 2 > 3

3.3 Nursing Competence, Sex Differences, and Three Course Program

Among the female students, continue-two-year-program students (3.66 ± 0.59) reported a higher level of overall nursing competence than did five-year-program students (3.35 ± 0.58) ($F = 11.599$, $p < .001$). The nursing competence of male students did not significantly differ by programs ($F = 1.036$, $p = .370$). For four-year-program students, there was significant differences in gender ($t = -3.122$, $p = .002$), the male (3.98 ± 0.43) higher than female (3.47 ± 0.59) (Table 2).

4 Discussion

The competence of nursing graduates is an important issue in health care as it is related to professional standards, patient safety and the quality of nursing care. We investigated nursing graduates ‘ perceived nursing competencies and its difference in three TVE programs. The mean nursing competency score of the participants was 3.50 (out of a total possible score of 5). The participants' scores indicate medium to high level of professional competence, and the level exceeded the median on the nursing competence scale. Additionally, the study showed that professional competence was significantly different in the three TVE programs. This finding is consistent with a previous study, which indicated that subjects perceived medium to high level of professional competence [20]. Furthermore, in this study, participants from all three TVE programs rated communication ability as the best nursing competency, followed by the ability to take care of patients. These results are consistent with those of Lin et al.'s study [21] which investigated the competence appraised by nurses and clinical nursing teachers; however, this finding was different from that of Hsu et al.'s study [20], which indicated that subjects perceived ability to care for patients as the best nursing competency, followed by communication ability. The differences could be attributable to the sample size (N = 31 vs. N = 365) or the different scales on nursing competence. Moreover, in these studies, research ability was rated the lowest, followed by management ability. Nursing education aims to provide students with basic nursing professional competence and the ability to provide high-quality care to the general public in response to the changes and challenges in the clinical setting [22, 23]. The goal of technical education is to foster care professionals who meet the needs of the workplace. The findings showed that the low scores on research and management abilities were acceptable. However, it showed that to developing nursing students' research and management ability is worthy of attention.

Most importantly, the results of the present study showed that the difference in professional competence with three TVE programs differed by program type. If it is in line with the speculation, participants who received the longest training and more credit hours should have scored higher on professional competence. However, in this study, the four-year program students (128 credit hours for four years) self-evaluated higher professional competence than did five-year program students (220 credit hours for five years). The study of Hsu et al. [20] showed that nursing competence was not correlated with the score required to pass the nursing licensure examination. The data analysis based on the private files in school in 2017 (Chung Hwa University of Medical Technology, data on files) also revealed that the five-year program students had better scores required to pass the nursing licensure examination than did four-year program students. These results and situations could be due to the following possibilities. The nursing competence scale was developed based on the eight core competencies for BSN degree students. Students from five-year junior colleges receive an associate degree upon graduation and continue-two-year-program at colleges of technology (accumulated seven years in training), and four-year program students receive a bachelor's degree upon graduation. Therefore, five-year program students scored lower on the nursing competence scale. Others possibilities could include the characteristics of the five-year program students, a younger age when enrolling in the nursing program or students' younger age could result in poor self-confidence regarding professional competencies. However, the actual reason is worth exploring.

The nursing competence of male four-year-program students in this study was significantly higher than female students. Although a disproportionate amount of men responded to the current survey, a review article summarized and indicated the advantages for men in nursing, including less likelihood of being punished by their female nursing instructors in the clinical setting and faster and more straightforward career progression than women [24]. The advantages of male students in clinical learning may lead to a better self-evaluation of nursing competencies than do female students. In short, the factors leading to significant gender differences in self-evaluation nursing competence is worth exploring.

The current study investigated nursing graduates' perceived nursing competencies and its differences in three TVE programs. Nursing graduates self-assessed their nurse competence as good. However, other evaluation methods could be used alongside to ensure that nurse competence can be completed and evaluated critically. In the future, it is important to understand the factors influencing nursing competencies, such as education curriculum designs, the reason for pursuing nursing, type of career choice intention, and professional commitment, and identify which factor is associated with nursing competencies and different vocational education programs.

5 Conclusions

Professional competency was significantly different in terms of the length of nursing students' vocational education. The mean nursing competencies score of the students was 3.50 (out of a total possible score of 5); that it is not far from satisfactory. Subjects perceived communication ability as the best nursing competency, followed by the ability to take care of patients; research ability was rated the lowest, followed by management ability. Future studies should examine how nursing students' professional competency can be improved and which nursing competency dimensions need to be emphasized. Educators should work according to their educational goals. Evaluating nursing students' competency may be used as an indicator of nursing education outcomes. It could facilitate the development of an improved curriculum and clinical teaching in nursing vocational education.

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Technology-Based Training

Adaptive E-learning for Supporting Motivation in the Context of Engineering Science

Mathias Bauer(✉), Cassandra Bräuer, Jacqueline Schuldt, and Heidi Krömker

Ilmenau University of Technology, Ilmenau, Germany
{Mathias.Bauer,Cassandra.Braeuer,Jacqueline.Schuldt, Heidi.Kroemker}@tu-ilmenau.de

Abstract. Current e-learning environments rely on adaptive user-centered approaches rather than static learning material, that is presented to the learner in a linear way, to maintain motivation and prevent learning blocks. The goal of the research project "SensoMot - Sensor Measures of Motivation for Adaptive Learning" is to detect critical motivational incidents based on sensor data and self-reports. By deriving suitable adaptation mechanisms, the learning process should be controlled to match the learner's motivation. Learning blocks should be detected at an early stage by means of unobtrusive, non-reactive sensors and the learning contents should be adapted accordingly. The focus of the present study is especially on the adaptation in e-learning for supporting motivation in the context of engineering science.

Keywords: Adaptation · Adaptive E-learning · Engineering science Focus groups · Motivation · Layered evaluation · User as wizard

1 Introduction

The context of engineering studies is characterized by extensive basic knowledge, which is acquired in the first semesters and later linked to domain-specific knowledge. Therefore, the Ilmenau University of Technology worked together with associations and companies to develop an e-learning platform for micro-nano-integration. The application area of the resulting NanoTecLearn platform [1] shall now be shifted towards university learning. Within this scope the platform will be transformed into an adaptive version that adjusts its instruction based on the current learning motivation. The research question to be answered in the investigation is: Which adaptation techniques are suitable for an e-learning platform that will maintain and improve motivation during the learning process? Paragraph two, theoretical framework, introduces in the subject of motivation in e-learning and adaptation in e-learning in the context of engineering science. The following paragraph three outlines peculiarities of adaptive systems. Paragraph four briefly describes the case study methodology that underpins this research. In paragraph five the results are presented and key findings are discussed.

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Paragraph six concludes the paper by highlighting its contributions as well as recommendations for future research.

2 Theoretical Framework

Adaptive learning environments have proven to be effective, but their development requires relevant knowledge of the interactions between the learner's personality traits and the characteristics of the learning environment [2].

Therefore, a cognitive-motivational process-model of self-regulated learning is used as a framework for describing the effects of the interrelation between person and situation factors on the learning outcomes [3]. As shown in Fig. 1 the framework starts with the antecedents of the current learning motivation that result indirectly in learning outcomes [3]. Besides demographic variables and prerequisite domain-knowledge several motivational person factors are included like self-efficacy beliefs [4], domain-specific interests [5] and two kinds of incentives as forms of intrinsic and extrinsic motivational orientation [6]. The mediating variables concentrate on the learner's emotional functional state due to conceptual similarities between motivation and emotion.

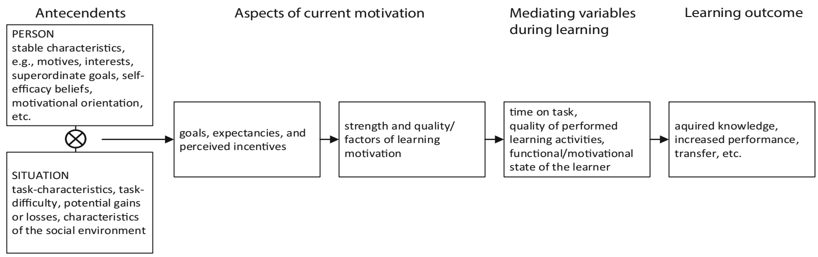


Fig. 1. Framework for learning motivation and its effects on self-regulated learning [3]

2.1 Motivation in E-learning Contexts

Motivation is "a theoretical construct to explain the initiation, direction, intensity, persistence, and quality of behaviour, especially goal-directed behaviour" [7], p. 3 in [8]. Motivation in e-learning contexts is not only complex and multifaceted but also situation-dependent. Online education, until now, has been under-researched and unfortunately under-utilized in the ways the SensoMot project team has attempted to design learning experiences. [8].

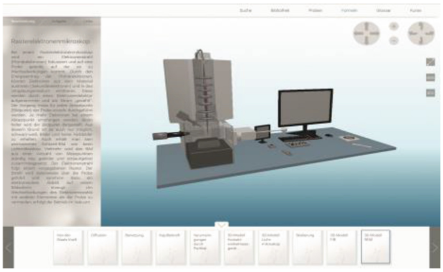
Hartnett's studies [8] have helped to narrow this gap and to understand the nature of motivation of online learners. She outlines comprehensively the rich and subtle interplay between learning design, grading requirements, personal tendencies, contextual needs, community behaviors, peer support, implicit and explicit pedagogies, as well as technological constraints.

Within the SensoMot project motivation is measured in two ways. Firstly, learners have to give self-reports about their current motivation at certain points within the platform. Secondly, the project evaluates the suitability of consumer wearables such as smartwatches and fitness trackers for the collection of sensor data, which then could be used to measure motivation.

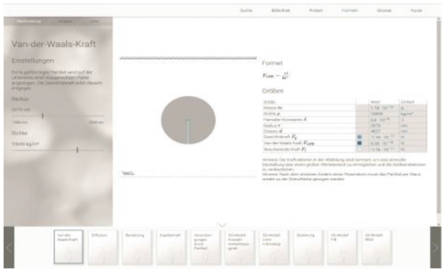
2.2 E-learning in Engineering Science

E-Learning offers the learner greater choice over how to study, including over what pace, what tools, what content and what methods to use. This individual control potentially increases on the one hand learner's autonomy and on the other hand provides greater support for their competence needs.

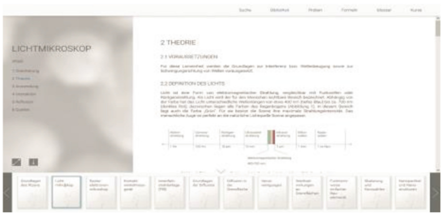
NanoTecLearn is an e-learning platform that provides new media and didactic opportunities for acquiring competences specifically in the area of engineering sciences [9]. Three chairs of the Ilmenau University of Technology worked together with associations and companies to develop this e-learning platform for micro-nano-integration. The platform is suitable both for self-learning and as a basis for further education with teachers. A flexible knowledge access was created through formulas, samples, 3D models and texts (see Fig. 2). The platform therefore, provides a very good base for an adaptive system since it offers learners different approaches according to their knowledge background and learning preferences.



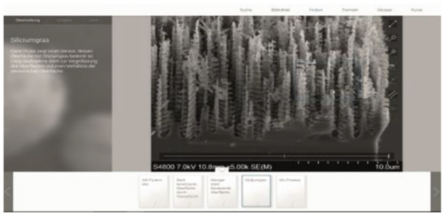
Interactive 3D model



Interactive formula



Text and images



Interactive samples

Fig. 2. Screenshots of the e-learning platform "NanoTecLearn"

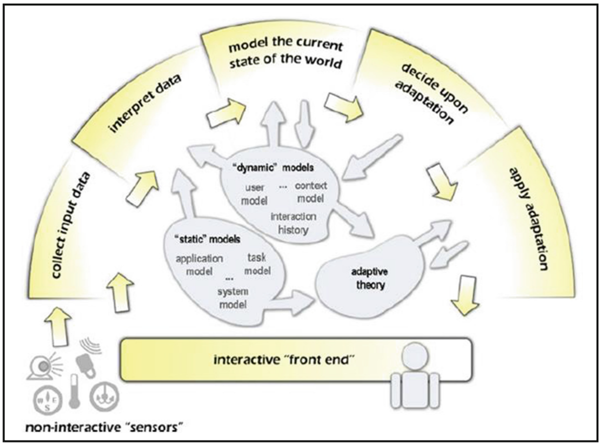


Fig. 3. The adaptation decomposition model [14]

2.3 Adaptive E-learning

Adaptation refers to the extent to which a learning environment adapts to different conditions (learning characteristics, learning progress, interests, etc.) [2]. The adaptation may relate, among other things, to the amount of instruction, the learning time, the sequence of topics, the time of the task presentation or the difficulty of tasks [10].

Adaptive learning is an approach to prevent drops in motivation in e-learning sessions and to optimize user-centered learning, but an underlying qualitative didactic concept is necessary. Moreover, in order to develop user-friendly adaptive e-learning, it is important to deal also with the basics of adaptive systems.

3 Adaptive Systems

The didactic concept of SensoMot is to systematically improve the fit between learners and the learning situation through adaptation. While in natural teaching-learning-settings, the fit can be easily improved by a properly trained teacher, this is hardly possible in technological teaching-learning situations. A system equipped with adaptive technologies should be able to respond to critical learning events and then adapt the learning content. This is done by creating a user model, which continuously collects information about the current state of the user and acts accordingly [11].

The kind of information stored in the user model depends on the context of the adaptive systems. Within the SensoMot project the system is an e-learning platform, so the user model contains information like domain specific knowledge, course of study and the usage history of the platform.

At the heart of the user model is the measurement of motivation. Critical motivational incidents will be used as instigators for adaptation. Once a change in motivation is registered by the system, it will perform a qualitative assessment of the change and recommend the user appropriate content to compensate for either loss in motivation.

4 Method

4.1 Underlying Evaluation Concept

The effectiveness of adaptive systems is highly reliable on the acceptance by users. To ensure a high degree of acceptance, it is imperative to include the user early on in the design process. The NanoTecLearn platform did just that with a comprehensive analysis of requirements as well as several usability tests. The SensoMot project aims to proceed in the same way.

Therefore, the design process follows the adaptation decomposition model as described by [14]. The model is the foundation for a formative evaluation approach, which allows the assessment of the different components of an adaptive system during all development stages.

The evaluation of adaptive systems is not as straight forward as one would expect. A simple comparison of an adaptive and a non-adaptive version of a system may lead to unsatisfactory results. As discussed in [15] a layered evaluation approach can help to better understand the process of adaptation. Due to the separation of different adaptation components, errors in the behaviour of an adaptive system can be clearly identified and improved upon.

The approach furthermore offers a wide range of different research methods for each adaptation component as well as the development phases. Therefore, it supports a comprehensive and user-centered design process.

This paper focuses on the evaluation of the layers' adaptation decision and adaptation application in the specification phase. That means, the functionality of the adaptation is clear but there has yet to be decided which technique will be used.

4.2 Choosing a Suitable Adaptation Technique

The aim of the SensoMot project is to improve the NanoTecLearn platform further with the special target group of university students in mind. Currently, the platform supports explorative learning, without a strict sequence or priority of learning contents. If the platform is to be used as an accompanying learning resource for students in attendance of certain lectures, this must be changed. Furthermore, the three content types – text, formula and sample – provide excellent motivational opportunities. Students whose motivation is decreasing during the reception of text may be redirected towards an interactive sample that visualises the content of the text and allows for manipulation. To implement this change of learning content is simply a question of navigating the learner to suitable material within the platform.

The authors of [12, 13] give an overview of different adaptive techniques and methods. One of which is adaptive link annotation. This method describes how relevant and non-relevant links are represented in the adaptive system. Links to content that is not relevant to a learner could be dimmed (so they are less visible and prominent) or they could be disabled all together. Links to relevant content on the other hand should be annotated or highlighted. This could be done by using different colors, text fonts and sizes or by using icons and symbols. The key aspect is that these annotations try to guide the learner's attention towards certain contents, but in the end the learner herself decides to click on them. Therefore, the highlighted links act as a recommendation and offer the user maximum control over where to go. Especially when the topic is very complex and the learner does have limited to no domain specific knowledge, it might be hard for her to make an informed decision on which highlighted link to follow. For this kind of learner, a strict sequence and guidance through the learning contents may be beneficial. This kind of behaviour is represented by the adaptive technique direct guidance. Here, the system again identifies relevant content for the learner, but instead of highlighting the link to this content segment, a new link appears. This could be for example, a simple button with the label “continue”. All other links are disabled and therefore the learner has no other option but to follow the link on the button. Therefore, she has no control over where to go and has to trust the system to make the right choices.

Both of these techniques solely rely on the interpretation of sensor data respectively self-reports about the current motivation of the learner. Due to this, they can only become active when the systems registers a change in this data. Unfortunately, this data gives no explanation why the change happens. It may be possible to infer reasons from the kind of content a person is looking at, but the cause might also be outside the system. This is where an entity similar to a pedagogical/educational agent can provide guidance. Educational agents are interface agents: software agents that are represented on the screen. Educational agents may also have adaptive functionalities, but this is not a necessary requirement for using the term. The term “pedagogical” is based on the fact that only agents are meant to be used in a specific application context: in multimedia learning environments [16]. In this case, the agent could always be represented on the screen. If the system registers a change in the data, it would give the user different content segments to choose from. For example, it could ask the learner if she would like an explanation of important terms or answer some questions about the text she just read. On the other hand, the learner herself could become active and ask the agent for suggestions or specific contents. These suggestions would be represented as link to different content segments.

The adaptation techniques, summarized in Table 1, are viable options for the implementation in NanoTecLearn within the SensoMot project. They make use of the diverse content structure of the platform and improve upon the navigation through the platform. The next step after identifying these techniques as viable option for the NanoTecLearn platform would be to get a user perspective on adaptation as a whole as well as the techniques. Therefore, focus groups with students at the Ilmenau University of Technology were conducted. These will be described in Sect. 4.3.

4.3 Users’ Perspective on Adaptation

The adaptations should not only have a user-friendly user interface, but also should be didactically meaningful embedded. In preparation for the prototypical implementation of an adaptive system, focus groups are conducted with students to take learners’

Table 1. Characteristics of the adaptation techniques link annotation, direct guidance and agent

Technique	Link annotation	Direct guidance	Agent
Functionality	Highlight relevant links	Guide the user through relevant content	Suggest relevant content
Learner control	High, highlighted links serve as a recommendation, learner chooses which link to follow	Low, learner cannot choose any other link Learner does not know where the systems guides her	High, agent suggests relevant content Learner can become active herself

perspectives into account. Especially four questions should be answered through the focus groups:

- What are potential reasons for changes in motivation during the learning process?
- Which countermeasure or adaptations would students want?
- How should these adaptations be represented?
- Which factors influence the acceptance of these adaptations?

To answer all these questions, the focus group contained two different parts. First students discussed questions related to these four aims moderated by a member of the research team. Afterwards the participants were split into two groups and took part in a user-as-wizard experiment. In this experiment potential users of a system have to put themselves into the position of the adaptive systems that has to decide what to do once the motivation of a learner changes. Each group received a fictional user persona which represents the current learner of the systems. The task of the participants was to think about how this persona would use the NanoTecLearn platform to achieve her goal and how the platform would react if the motivation of this persona changes.

The discussion mainly concentrates on why motivation may change as well as what countermeasures students would wish for. Whereas the user-as-wizard experiment generates an understanding of the adaptation process and techniques potential users would expect from the system. Building upon these findings, the SensoMot project intents to develop an adaptive prototype which modifies the content sequence according to the current motivation of the learner. The sequence will be changed with the help of the three afore mentioned techniques, each technique will be implemented in a separate prototype. This allows a comparison of the learning experience as well as usability factors for each technique.

Participants of the Focus Group. Between January and February 2018 four focus groups were conducted. Each focus group had between 4 to 5 participants, so that a total of 19 students took part in the study. The students were mainly enrolled in courses that had lectures concerning the topic of micro-nano-integration, which is also the topic of the NanoTecLearn platform. Other students had a background in media economics as well as media studies. These students offered a different perspective on multimedia learning and e-learning. All four focus groups consisted of a mixed group of subjected related and not related students.

The students were recruited via their participation in another study concerned with the measurement of motivation during the learning process as well as e-mails to different student mailing lists. Each participant received 30 Euros as a recompense.

Procedure of the Focus Groups. As described earlier, the focus group consisted of two parts, the discussion and the user-as-wizard experiment.

The following observation methods were used:

(a) focus group observation (video recording from two perspectives each)
(b) direct focus group observation including behavioral observation using an observation sheet

A brief overview of the procedure of the focus group and experiment are shown in Fig. 4.

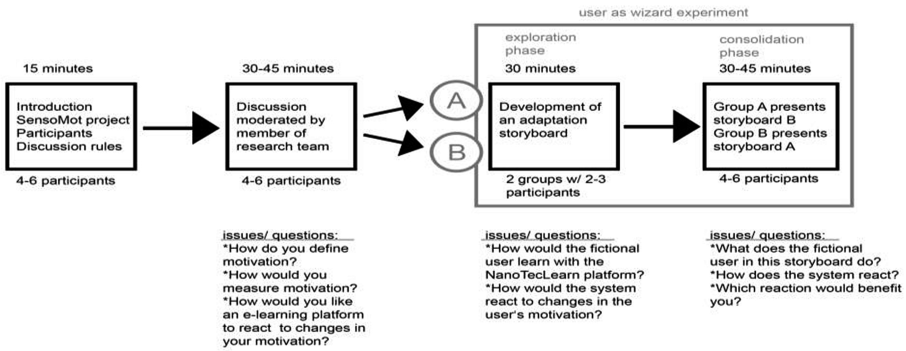


Fig. 4. Model of the focus group procedure

The focus group started with the introduction of the research project, the participants as well as some basic rules. After the explanation of the rules the video and audio recording was started. The whole process was also observed by a member of the research team through a one-way mirror. This person was responsible for creating a brief observation sheet. The observation sheet included some general information about the focus group, e.g. date, group size, male/female participants, used personas, in the first section and a follow-up observation on the different tasks in the second section. The follow-up observation was documented with time stamps, concerning the topic, what is happening right now and role aspects of the subjects were noted.

Next the participants were asked how they define motivation and how they could imagine measuring motivation. Then the discussion continued with the topic of adaptation. The participants should present their ideas how a system could react when it realizes the motivation of a learner changes. Subsequently, the adaptation process was explained with the help of the decomposition model shown in Fig. 3.

The NanoTecLearn platform was briefly introduced and the task for the user-as-wizard experiment was explained. For this experiment the group was split into two smaller groups of 2 to 3 people which occupied separate areas of the room. Each group received a fictional user persona as well as a template for a storyboard. The task of each group was to first: think about how their fictional persona would use the NanoTecLearn platform to achieve his or her goal. Both groups had access to the platform on a computer or laptop. Second, they had to identify when the motivation of this persona may change and how the systems should react to that. Each persona worked with a certain topic on the platform, which was divided, into several chapters.

The storyboard should contain information about the chapter the persona is currently working on as well as the chapter before that. Additionally, the current motivation at the end of the chapter as well as the motivation at the beginning of the chapter should be noted. The participants should describe if and why the motivation changed during each chapter and how the system should react to this change. They also had the opportunity to make sketches of how the reaction of the system could look like.

After roughly 30 min, the two groups returned to the center of the room and exchanged their storyboards. Each group had a few minutes' time to familiarize themselves with the ideas of the other group. Then the groups presented the work of the other group briefly, while the creators of the storyboard had the opportunity to intervene when there were mistakes. After their presentation, the group should comment on what they just presented. The focus was on their personal perception of the ideas as well as their assessment of the suitability of the ideas. Then the second group had to present the storyboard in front of them. The experiment ended with a discussion of both storyboards and further ideas.

5 Results of the Qualitative Content Analysis

As a result of the four focus groups conducted in January and February 2018, there were more than six hours of video and audio material and 120 pages of transcript. The focus groups were successfully performed, the records were transcribed and evaluated using MAXQDA. The communication and cooperation worked well in all focus groups, the tasks were carried out in a timely manner and each focus group presented two storyboards at the end of the session.

The composition of the four focus groups is shown in Table 2.

Table 2. Composition of focus groups

		Focus group 1	Focus group 2	Focus group 3	Focus group 4
Sample	n	5	4	5	5
Gender	Male	3	2	3	4
	Female	2	2	2	1

It is a qualitative analysis of focus groups with non-representative character. Qualitative statements do not claim to be static representatively and are more likely to provide suggestions for reflection. Relevant statements of the present transcripts were color-coded and merged into topics. The essential facts and answers of the students are presented to the questions in a keyword-like manner (Table 3):

Table 3. Clustered statements of students

What are potential reasons for changes in motivation during the learning process?	
Extent of learning material	**Length of texts** Motivation sinkt bei sehr langen Texten (P3 85:44-5) Bilder können eine auflockernde Wirkung haben (P2 87:00-1)
	Time needed for processing the content Motivation sinkt, wenn unklar ist wieviel zu tun ist (wenn z. B. keine Zeitangaben für eine durchschnittliche Bearbeitungszeit angegeben werden) (P3 84:48-3)
Structure of platform and learning material	**Structure of learning material: extent of learning material and division into smaller chunks, summaries, references to important literature** Umfang des Lernmaterials, lieber kleine Einheiten (P2 13:00-6) Quellen sollten im Text vermerkt sein (P2 97:53-6)
	Structure of platform: clear navigation structure, tutorial for beginners Motivation sinkt, wenn Navigationsstruktur unklar ist (P3 94:03-5) Es sollte eine Erklärung der Plattform/Navigation geben (P5 107:51-0)
Possibility for interaction with learning material	**Interaction opportunities to increase motivation** Motivation steigt, wenn man etwas ausprobieren kann (P1 87:03-3) Parameter verändern, und unmittelbar Ergebnis betrachten (P1 87:09-6)
Varying presentation of learning content	**Change the forms of presentation according to the requirements** Motivation steigt, wenn man Bilder einfach vergrößern kann und Unterschiede direkt gegenübergestellt werden (z.B. tabellarisch) (P3 96:47-5)
Relevance of learning material	**Value of different forms of presentation** Motivation sinkt, wenn der Mehrwert von bestimmten Darstellungsformen nicht klar ist (P3 103:12-7)

(*continued*)

Table 3. (*continued*)

What are potential reasons for changes in motivation during the learning process?	
Usage of symbols	**Clear meaning of symbols** Motivation sinkt, wenn die Bedeutung von Symbolen nicht eindeutig ist und man erst darauf klicken muss (P1 101:53-3)
Which countermeasure or adaptations would students want?	
Presenting progress through learning material	**Progress bar** Fortschrittsbalken, wenn ein Abschnitt bearbeitet wurde (P5 13:22-0) Es sollte eine Fortschrittsanzeige geben (P1 84:14-7)
Presenting same content in different ways	**Different media format** Lange Text sollten mit Bildern aufgelockert werden. Es sollten Videos als Alternative für den Text angezeigt werden können (P3 85:44-5) Überleitung zu anderer Darstellung von Inhalten (Zusammenfassung, oder Interaktion) wenn Lernende lange nicht aktiv sind (P3 15:28-2)
Tasks and interaction	**Exam questions, interaction for a better understanding** Die Plattform sollte Kontrollfragen bieten (P1 27:46-0) Die Plattform sollte Prüfungsfragen enthalten, die Aufschluss darauf geben welche Schwerpunkte gesetzt werden (P2 29:16-9) Die Interaktionen sollten weitere Erklärungen oder Wiederholungen des Stoffes aus der Theorie bieten (P5 108:41-9)
Definition of important terms	**Explanation of foreign words and terms** Fremdwörter/wichtige Begriffe sollten erklärt werden, Erklärung sollte zugänglich sein ohne dass der Text verlassen werden muss (P3 95:14-8) Definitionen im Text sind wichtig (P5 95:36-3)
Learner control	**Structuring learning process** Möglichkeit völlig frei zu Lernen oder eher vorstrukturiert (P3 22:25-9) Es sollte möglich sein, Abschnitte innerhalb eines Booklets zu überspringen (z.B. von Orientierung zu Zusammenfassung) (P4 88:37-8; 88:46-6) Plattform sollte einen Arbeitsplan erstellen können (P5 26:43-4)
Social aspects	**User account, forum, chat function** Die Plattform sollte Benutzerkonten haben in denen auch Freunde verzeichnet sind, die ebenfalls mit der Plattform lernen (P5 30:53-8)
Learning strategies	**Choose from different learning strategies** Verschiedene Lernstrategien aufzeigen, auswählen und in der Plattform danach lernen, wenn die Strategie nicht passt einfach zu anderer Strategie wechseln und wenn möglich Fortschritt beibehalten (P3 22:25-9)

How should these adaptations be represented?	
Symbols and icons	**For feedback on status: different kinds of contents, special terms** Ein Symbol rechts oben am Wort (z.B. Dreieck) mit dem man durch Anklicken ein PopUp öffnen und wieder schließen kann (P3 95:14-8) Die Fachbegriffe sollten mit einem Viereck mit einem Pfeil in der Mitte gekennzeichnet werden (P1 96:06-0)
Table of contents	**Outline of topics/structure into subject areas** Eine ausführlichere Gliederung am Anfang wäre hilfreich (P4 89:25-1) Die Gliederung am Anfang sollte zunächst alle groben Themenbereiche zeigen, bei Klick werden die Unterpunkte angezeigt (P1 90:02-4)
PopUps and overlays	**For additional content** Begriffserklärungen sollten als PopUps im Text dargestellt warden
	For communication with the user Diese PopUps wären für manche Nutzer nervend, da sie gern die Plattform durchklicken möchten um einen Überblick zu haben (P3 89-19-0)
Addressing the user	**Feedback and support when motivation decreases** Ansprache bei sinkender Motivation neutral (nicht du bist zu blöd, sondern hier gibt es etwas, wenn es dich interessiert) (P416:21-6)
Which factors influence the acceptance of these adaptations?	
Learner control	**Assistance in learning, but not patronizing** Darf nicht zu stark das Umfeld kontrollieren, z.B. soll die Plattform nicht verhindern, das im Browser andere Fenster geöffnet werden (P1 17:50-5) Durch den Arbeitsplan soll man planen können, aber das Programm soll nichts vorschreiben (P5 26:47-7)

6 Conclusion

Conducting the focus groups provided the participating students with a structured framework for critically discussing the NanoTecLearn platform and identifying potentials for improvement. In addition, the developed approaches and ideas for the modification by the target groups were critically examined and new suggestions for adaptation techniques were collected. During the focus groups, it became apparent that it was hard for these students to think of adaptive mechanisms that could support their learning. Each student has a personal learning strategy, which is specific to this student. Therefore, they are skeptical if an e-learning platform can really cater to their diverse needs. Nevertheless, they discussed very amply which contents and presentations of this content would support their learning. A similar challenge was noticeable during the user-as-wizard experiment. The students had no problems to put themselves in the position of the fictional users. Imagining how this persona would use the e-learning platform NanoTecLearn and when he or she would suffer from a lack in motivation did not form an obstacle. However, when it came to putting themselves in the position of the platform and thinking about ways to react to these drops in motivation, it became challenging for the students. Therefore, the storyboards are missing the reactions of the system to the identified changes in motivation. An idea to improve upon this situation would be to abstain from using fictional personas and instead let the students describe their own learning path through the platform.

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Achievement of Sanitary Learning by Problem-Based Learning (PBL)

Jaruwan Chutrtong[1(✉)] and Waradoon Chutrtong[2]

[1] Industrial Microbiology, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand
jaruwan.ch@ssru.ac.th
[2] Chemistry, Faculty of Science, Srinakarinwirot University, Bangkok 10110, Thailand
waradoon@swu.ac.th

Abstract. This research conducted with the following objectives: to study the effectiveness of learning sanitation subject by Problem-Based Learning (PBL) and to study students' satisfactions of learning by PBL. The results found that mean scores from the formative evaluation of work behavior according to the lesson plan learning by problem-based learning are equal to 85.56%. The mean scores of the achievement test before learning are equal to 20.20 of 30 scores and the mean scores after learning is equal to 25.67 of 30 scores. This indicated that the efficiency of the sanitary learning by PBL after learning was higher than the efficiency before learning. The students' satisfaction with learning by problem-based learning were in high level, and their satisfactions with each item were also in high level.

Keywords: Achievement · Sanitary · Problem-Based Learning

1 Introduction

Problem-Based Learning (PBL) is a form of learning that arises from concepts based on creative learning theory (Constructivism) [1]. It was developed in 1969 [2] and become a popular education model internationally. PBL allows learners to build on knowledge from the real world problems. Students will develop their thinking and problem solving skills. They also gain knowledge in their subject area. In terms of teaching strategies, PBL is a teaching technique that encourages students to practice self-efficacy, confronted with the problem.

The PBL teaching model is still argumentative. Although PBL model presents certain advantages with respect to improving student abilities in inactive learning, two-way communication, thinking and teamwork, relative to traditional lecture-based learning (LBL) models [3], but the LBL teaching model is responsible for the acquisition of theoretical and fundamental knowledge [4].

In sanitation subject, the problem of student's learning by lecture-based learning is due to the lack of skill in systematic thinking development [5, 6]. It is used as a guideline to solve the problem of sanitation effectively. As a result, they cannot solve a variety of problems that arise in conflict with the philosophy of modern learning

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management [7], focusing on different styles of learning to make the most of student achievement.

However, a systematic, quantitative assessment of the outcomes of PBL teaching model application during learning of sanitation courses has not been conducted. For this study, we have compared the effects of PBL and LBL teaching models on the test score of undergraduate sanitation subject in Suan Sunandha Rajabhat University, thereby for evaluating the feasibility of PBL application. The expected benefits of this study is to find teaching methods that lead students to integrate old knowledge and new knowledge together. Students can synthesize new knowledge that can use to solve problems.

2 Research Objectives

To measure the effective of learning sanitation subject by Problem-Based Learning (PBL) compare with lecture-based learning (LBL) models and study the satisfactions of students with learning and teaching by PBL.

3 Research Question

The research questions for this study were:

1. How do learning outcome of students in the sanitation topic by problem-based learning? (Measured by the development of the scores obtained from before and after the study)
2. What do skills development of the students after using problem-based learning management?
3. Which level of student satisfaction with problem-based learning management?

4 Research Hypothesis

The research hypothesis for this study were (Figs. 1, 2 and 3):

1. The results of PBL learning management promote positive development of work skills and problem solving approaches for students.
2. Students are satisfied with the problem-based teaching and learning in the medium to good level.

Fig. 1. Research hypothesis.

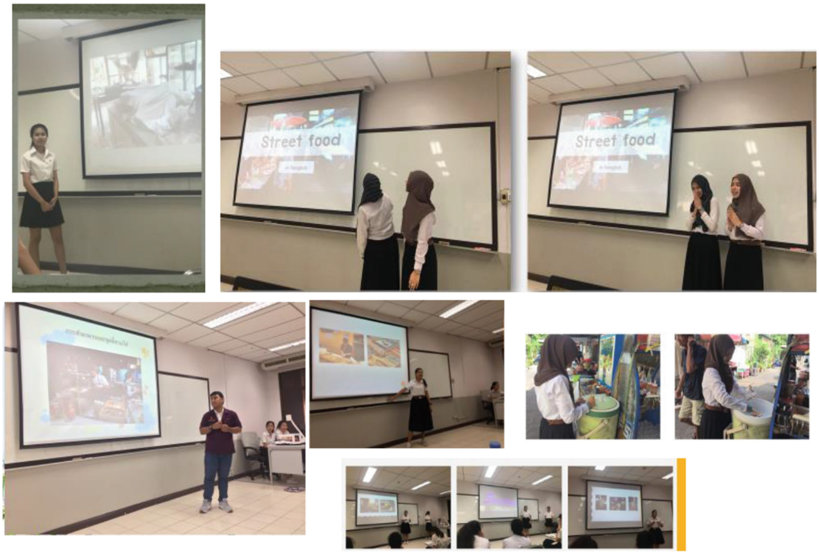

Fig. 2. Student presentation

Fig. 3. Student works on sanitation topic by PBL model

5 Research Scope

Population of this research were 26 students of third year of industrial microbiology student of department in Quality control course for the 1st semester of academic year 2017. The scope of content was to study the effect of problem-based learning management on the development of teaching and learning in sanitation by measurement of changes in learning outcomes compare between before and after test. Problem identification, problem solving and solution design (three essential skills assessment techniques) are identify.

6 Advantage

The expected advantage from this research are:

1. To know effect of applying problem-based learning used to improve teaching and learning of sanitation concept
2. To improve new methods for teaching and adapt the development and abilities of each student

7 Method

All ethical clearances and written consents were taken from concerned authorities before conducting the study. A well-designed, scientifically tested questionnaire was given to all students in the beginning. This questionnaire was include with short answer and multiple choice questions of the content about sanitation which already taught by lecture-based learning (LBL) models. After that, problem based learning sessions were conducted. The topics were same as in the traditional lecture. Subjects divided into 7 groups. Each group was given problem. They had 2 week to prepare for the presentation. After presentation, post-test questionnaire was administered. Student's feedback to assess the effectiveness of PBL sessions was taken based on questionnaire on the five-point scale comprising: strongly agree (5); agree (4); undecided (3); disagree (2); and strongly disagree (1). Completed questionnaires were collected and data analysis use the statistics of the development of students before and after the study (Growth Score), including the percentage, the average of the survey combined with content analysis from observation form and educational achievement analysis. P-value < 0.05 was considered statistically significant.

8 Result

The research study on 4 parts as follows.

1. General information of students
2. The development of the academic achievement, compare between pre and post, effect from using the problem as base for learning.
3. Development of work skills in accordance with the objectives of the course.
4. Student satisfaction on problem-based learning management and the advantages and disadvantages of using problem-based learning.

8.1 General Information of Students

See Table 1.

Table 1. General information of students

Information	Number	Percent
Sex		
– Male	3	11.54
– Female	23	88.46
Age		
– 20 year old	2	7.69
– 21 year old	22	84.621
– 22 year old	2	7.69

8.2 The Development of the Academic Achievement

Students average score on lecture-based learning (LBL) models was20.20 from full score 30, ranked as pre-test score 30 points. The average of score was 25.67 from full score 30 after PBL trial. Most students get higher score. The average of the developmental correlations was 5.47, 18.23%.

8.3 Development of Work Skills

The students' average score for problem identification, problem solving and solution design were 22.9%, 16.64% and 15.5 percent respectively. After the problem-based learning management, the average design skill for problem solving was 25.00%, followed by problem solving skills 19 and problem-solving skills accounted for 19%.

8.4 Student Satisfaction on Problem-Based Learning Management

From questionnaire, the results of the study on the satisfaction of the knowledge gained from the problem-based learning management were at the high level. The score were as follows.

1. Students understood the principles and scope of the study. This got 3.75 point.
2. Students understood and could the meaning of the topics in this course. This got 3.2 point
3. Students understood and could explain the contents of the study. This got 3.59 point.
4. Students understood the guidelines that show how to study the topic. This got 4.00 point, the highest satisfaction.
5. Students understood step and could explain the study process. This got 3.5 point.
6. Students Understood and be able to perform tasks as assigned. This got 3.5 point.

7. Students Linked knowledge between content and practice. This got 3 point.
8. Students could identify the goals of the study. This got 3 point.
9. The satisfaction on explain and ask questions and give examples of the lecturer was 3.8 point.
10. The satisfaction on clarity of principles of the lecturer was 3.6 point
11. The satisfaction on teaching methods and tools of the lecturer was3.4 point.
12. The satisfaction on question and examples of the lecturer was 3.9 point.

9 Conclusion

An overview of the result, PBL teaching model application in undergraduate science courses can increase course examination rates and scores of the third year students of industrial microbiology department in Quality control course, sanitation topic.

The results of the comparison of the mean score on the development of skills on three aspects.

1. The problem solving design skills had the highest average development score. The problem had been solved since the beginning.
2. Problem solving skills had the mean score of improvement.
3. Problem specify skills had the lowest average development. However, there were many students could analyze the problem but unable to create systematic problem solving process. It showed that students lack the process of systematic problem analysis.

The results of student satisfaction on Problem-Based Learning indicated that the knowledge and understanding gained from this model had mean score 3.97, which was very high, and the issue of tools and methods of problem-based teaching had mean score 3.87, which was very high too.

From the study of problem-based learning management, it was found that most of students agree that the use of the problem as a base allows for a clearer view of the goals of work, and allows them to analyze data in order to create a more systematic concept. On the other hand, the disadvantage of using problem-based learning is that students take a long time to identify the problem because of lacking experience in the problem. Some problems could not be developed the target, concept and work design in limited time that cause confusion in data and work process more than ever. So that, teachers should be involved in helping to identify issues and work processes to students. This will affect the duration of students' work and make the problem clear than the students try by themselves.

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Language Training in the Philippines: Measuring and Exploring Learner Experiences

Chihiro Tajima(✉)

Gakushuin Women's College, Faculty of Intercultural Communication, Associate Professor, 3-20-1 Toyama, Shinjyuku-Ku, Tokyo, Japan
chihiro.tajima@gakushuin.ac.jp

Abstract. Although the traditional English language training destinations, e.g., the U.S., the U.K., and Canada, are still popular among Japanese learners of English, non-English speaking countries such as the Philippines have also gained popularity as they are relatively inexpensive study abroad destinations. The present study attempts to clarify the outcomes and experiences of language training in the Philippines. The participants of this study were 21 Japanese learners studying English in the Philippines for five weeks. This was a longitudinal study and the data were collected over a period of two months. The study was conducted using a mixed methods approach to report findings from both quantitative and qualitative data. In particular, this study employed an explanatory sequential mixed methods design [1]. The present study is designed to investigate, within one study, the outcomes using quantitative data, then seek explanations by exploring the language learning experiences through the qualitative data.

Keywords: Study abroad · Lingua franca · Higher education students
Sequential mixed methods design · Second language acquisition

1 Introduction

1.1 Language Learning Environment in Study Abroad Context

Learners in study abroad (SA) context have access to both in-class instructional and out-of-class natural language acquisition. The instructional acquisition setting pertains to when the target language is taught to a group of second or foreign language learners and the focus is on the language itself [2]. In contrast, the natural acquisition setting refers to when learners are exposed to the target language at work and in social interaction. In such a setting, the language is learned through the communication that takes place in naturally occurring social situations. As Kinginger summarizes, "Study abroad learners are a hybrid variety, with access to instruction but also with potential increases in their time-on-task and access to the language input and interaction believed to drive the acquisition process" [3]. Freed suggests that a hybrid environment provides the best setting for learning a language [4].

Other studies attempt to describe the benefits of the various SA language learning contexts. For example, DeKeyser listed five reasons why the SA context is an effective

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environment for language learning: (1) the number of hours spent in the native-speaking environment, which provides, (2) an enormous amount of comprehensible input, as well as speaking practice, (3) getting a number of things done in the language they are learning, which can, (4) influence their motivation, and (5) being able to interact with multiple native speakers, which is not typically possible in the classroom learning environment [5].

The context of SA in the Philippines, however, differs from that of the traditional destinations. For instance, language training in the Philippines does not offer a native speaking environment, and instead, learners engage in interaction with non-native English speakers (NNS-NNS interaction).

1.2 Development of Affect in Study Abroad Context

Development of learner affect in the traditional SA context has been reported. Willingness to communicate in second language [6] for SA learners is a key determinant in their ability to engage with native speakers, and this interaction facilitates the language acquisition process [7]. SA learners' pre-departure self-confidence in English is an important factor for increasing the amount of language contact while-abroad [8]. SA learners who improve their English proficiency also have higher levels of motivation upon return [9]. Only five weeks of studying abroad results in higher levels of self-confidence and higher motivation in learners [10]. For language anxiety, although some research reports that the exposure to interactions in the target language reduces the levels of language anxiety [11], other research reports that learners in the SA context experience different degrees of language anxiety depending on the context of their interactions. Moreover, anxiety level decreases only in controlled short interactions (i.e., service encounters), and the level remains high in more complex interactions, which involve cultural differences [12]. Pellegrino also explains that learners' anxiety changes depending on the interlocutors in the SA context [13].

1.3 Study Abroad Research in the Philippines

SA in the Philippines and SA contexts where English is used as a lingua franca are both under researched. Using the online Education Resources Information Center (ERIC), and searching through books and peer reviewed materials from 1999 to 2018, there was no relevant match found that included two keywords, *Philippines* and *study abroad* in the title, abstract, and descriptors. In addition, there was no relevant match found that included another set of keywords, *lingua franca* and the *Philippines*. Searching by a combination of *lingua franca* and *study abroad*, there was one slightly relevant study, which reports Catalan/Spanish students studying English in a lingua franca environment in European countries [14].

2 Method

2.1 Research Purpose and Research Questions

This study addresses outcomes of SA in the Philippines. An explanatory sequential mixed methods design is used [15], and it involves collecting quantitative (QUAN) data first and then explaining the QUAN results with qualitative (QUAL) data. In the first, QUAN phase of the study, English proficiency, willingness to communicate, motivation, and language question data are collected from 21 Japanese learners of English studying abroad in the Philippines to assess whether studying in the Philippines relates to English proficiency gain and affective factor improvement. The second, QUAL phase is conducted as a follow-up to the QUAN results to help explain the QUAN results. In this exploratory follow-up, the tentative plan is to explore the language learning experience with Japanese learners of English in the Philippines SA program, where English is used as a common language.

Considering above, three research questions were generated: (1) Will learners make English proficiency gain by studying in an English as a lingua franca environment for 5 weeks? (2) Will learners develop affective factors, i.e., willingness to communicate and motivation, and reduce language anxiety by studying in an English as a lingua franca environment for 5 weeks? (3) How do QUAL data of learner experiences explain the QUAN results?

2.2 Language Training Context

Participants. Participants in this study were 21 female Japanese university students from a private university in Tokyo, between the ages of 19 to 21. According to their English placement results at the time of their entry into the university, they were at an elementary to intermediate level of English (TOEIC equivalent scores ranging from 220 to 550). The main motivation for participating in the Philippine SA program was the reduced expense compared to going to the traditional SA destinations, such as the U.S., the U.K., Canada, and Australia. In addition, students with less confidence about doing a homestay in more traditional SA destinations were likely to be attracted to this particular program. Finally, for the participants, one-to-one language instruction was an appeal compared to traditional style classroom instruction.

Dormitory in the Philippines. The language training program was situated in Bacold, which is a city one-hour's flight away from Manila. Participants stayed in a dormitory next to the language training school. The dormitory housed international students mainly from Korea and Japan. In the common areas, such as a cafeteria where students had all three meals a day, the common language was English. Participants shared one room with another student from their home university, which allowed them to speak their native language, Japanese, inside the dormitory room. Due to security concerns, the dormitory had a curfew every day, except on Wednesdays and weekends. On these days, participants were allowed to be out with someone from the dormitory, but not alone.

English Training. For 5 weeks in the host country, the Philippines, participants took four hours of one-to-one English instruction per day and two hours of classroom instruction per day from Monday through Friday. The English instruction was provided by Filipino instructors, who spoke to them in their second language, English. In addition, during the five weeks, the participants visited two orphanages and took field-trips to the beach, organized and chaperoned by the program.

2.3 Data Collection Procedure

For this study, the QUAN and QUAL data were collected at the same two times; at pre-departure and post-return. For an explanatory sequential design in particular, data should be collected from the same participants [16]. Informed consent was received from all of the participants.

The study was longitudinal, with data collected at two separate times spread over two months as shown in Tables 1 and 2. Pre-departure data were collected around two weeks before departure. Post-return data were collected around two to five days after they came back from the Philippines.

Table 1. Pre-departure data (two weeks before departure).

QUAN/QUAL	Data
QUAN	English proficiency test
	Willingness to communicate questionnaire
	Language anxiety questionnaire
	Motivation questionnaire
QUAL	Interview

Table 2. Post-return data (2 to 5 days after returning).

QUAN/QUAL	Data
QUAN	English proficiency test
	Willingness to communicate questionnaire
	Language anxiety questionnaire
	Motivation questionnaire
QUAL	Interview

2.4 QUAN Data

The following section summarizes the measurement instruments listed in Tables 1 and 2.

Measurement of English Proficiency. To measure English language proficiency, the Computerized Assessment System of English Communication (CASEC) [17] was used. CASEC is a computer adaptive test (CAT) and measures (1) knowledge of vocabulary, (2) knowledge of phrasal expressions, (3) listening ability (understanding of main idea), and (4) listening ability (dictation). The test was administered twice; at pre-departure and post-return.

Measurement of Willingness to Communicate. Willingness to communicate in this study means being willing to communicate actively, looking for chances to communicate, and furthermore actually communicating in the second language. To measure willingness to communicate, some of the question items developed by Yashima [18] based on the willingness to communicate model [19] were used. For this present study, a questionnaire with eight items was administered twice; at pre-departure and post-return.

Measurement of Motivation. Gardener [20], in defining motivation, claims that four elements must be present for a learner to be considered motivated: a goal, desire to achieve the goal, positive attitudes, and effort. They are referred to as affective variables. The questionnaire, therefore, in the present study asked questions related to these affective variables, in addition to questions concerning integrative motivation [21], meaning the degree of desire to integrate into the host culture. This questionnaire was administered twice; at pre-departure and post-return.

Measurement of Language Anxiety. Language anxiety in this study is defined as fear or apprehension occurring when a learner is expected to perform in a second or foreign language [22]. To measure language anxiety, the question items from the foreign language classroom anxiety scale developed by Horwitz et al. [23] and personal report of communication anxiety questionnaire (PRCA) developed by McCroskey [24] were used to create a questionnaire consisting of four question items. The questionnaire was administered two times; at pre-departure and post-return.

2.5 QUAL Data

QUAL data consisted of interviews. As previously shown in Tables 1 and 2, the collection of QUAL data were pre-departure and post-return interviews. Interview prompts were of the semi-controlled type, meaning prompts were carefully chosen prior to interviews, to be sure to draw the necessary information from the participants.

At pre-departure and post-return, all learners were interviewed for approximately 20 to 30 min each. During the pre-departure interviews, learners were asked about any worries about their life in the Philippines. At post-return, learners were asked about their language learning in class, language use at their dormitory, and the highlight of their time abroad. The data were collected in Japanese, transcribed, then translated to English by the researcher.

3 Results

3.1 Quantitative Data Results for Research Question One

Research question one was to investigate the proficiency gain in the lingua franca SA context for 5 weeks. The following paragraphs describe the results.

English Proficiency Outcomes. The CASEC scores obtained at pre-departure and post-return were screened prior to the main analysis. There were found to be no outliers. The skewness and kurtosis z-scores confirmed that both the pre-departure and post-return data were normally distributed. The Cronbach's alpha reliability for the English proficiency test scores have been found to be in a .96 to .98 range [25].

The paired samples *t-test* result showed that on average, the participants had significantly higher scores on the CASEC test after they had studied abroad (M = 483.62, SE = 16.70) than before (M = 442.57, SE = 16.50), $t(20) = -3.23$, $p < .01$, $r = .34$). The result indicated that learners made gains in their English proficiency after studying abroad in the Philippines (Table 3).

Table 3. Descriptive statistics for English proficiency.

	n	mean	SD	min.	max	skew	kurt
Pre CASEC	21	442.57	75.62	274.00	603.00	−.20	.34
Post CASEC	21	483.62	76.51	274.00	628.00	−.68	1.67

3.2 Quantitative Data Results for Research Question Two

Research question two was to investigate non-linguistic development, i.e., development of willingness to communicate and motivation, and reduction of language anxiety.

Willingness to Communicate Outcomes. The willingness to communicate questionnaire scores obtained at pre-departure and post-return were screened prior to the main analysis. There were found to be no outliers. The skewness and kurtosis z-scores confirmed that both the pre-departure and post-return data were normally distributed. The Cronbach's alpha reliability for the willingness to communicate questionnaires were satisfactory (pre-departure: $\alpha = .90$, and post-return: $\alpha = .90$) as shown in Table 4.

Table 4. Descriptive statistics for willingness to communicate.

	n	mean	SD	min.	max	skew	kurt	alpha
Pre WTC	21	.46	.20	.08	.90	.07	.05	.90
Post WTC	21	.66	.19	.13	.93	−1.05	1.74	.90

The paired samples *t-test* result showed that on average, the participants had significantly higher willingness to communicate in English after they had studied abroad (M = .6567, SE = 16.70) than before (M = .4581, SE = 16.50), $t(20) = -6.08$, $p < .01$, $r = .65$). The result indicates that learners developed their willingness to communicate after studying abroad.

Motivation Outcomes. The motivation questionnaire scores obtained at pre-departure and post-return were screened prior to the main analysis. There were found to be no outliers. The skewness and kurtosis z-scores confirmed that both the pre-departure and post-return data were normally distributed. The Cronbach's alpha reliability for motivation was low (pre-departure: α = .71, and post-return: α = .49) as shown in Table 5. However, values below .70 could be expected with psychological constructs because of the diversity of the control was measured [26].

Table 5. Descriptive statistics for movitation.

	n	mean	SD	min.	max	skew	kurt	alpha
Pre Motivation	21	.69	.16	.45	.95	.11	−1.20	.71
Post Motivation	21	.83	.10	.65	.95	−.53	−.84	.49

The paired samples *t-test* result showed that on average, the participants had significantly greater motivation to study English after the overseas study period (M = .8262, SE = 16.70) than prior to it (M = .6929, SE = 16.50), $t(20) = -4.98$, $p < .01$, r = .55). The result indicates that learners developed their motivation after studying abroad.

Language Anxiety Outcomes. Language anxiety questionnaire scores were screened, and there were found to be no outliers. The skewness and kurtosis z-scores confirmed that pre-departure and post-return data were normally distributed. The Cronbach's alpha reliability was satisfactory (pre-departure: α = .92, and post-return: α = .92) as shown in Table 6.

Table 6. Descriptive Statistics for Anxiety.

	n	mean	SD	min.	max	skew	kurt	alpha
Pre Anxiety	21	.75	.26	.10	1.00	−1.30	1.06	.92
Post Anxiety	21	.57	.28	.10	.95	−.168	−1.12	.92

The paired samples *t-test* result showed that on average, the participants had significantly less language anxiety after they had studied abroad (M = .5714, SE = 16.70) than before (M = .7478, SE = 16.50), $t(20) = 3.30$, $p < .01$, r = .35). The result indicates that learners lowered their language anxiety after studying abroad.

3.3 QUAL Data Results for Research Question Three

Research question three was aimed at exploring QUAL data of learner experiences to explain the QUAN outcome results. The data reduction was performed based on the QUAN data results, and learners with the following criteria were chosen for analysis: (1) proficiency gain, (2) increase in willingness to communicate levels, (3) increase in motivation levels, and (4) decrease in language anxiety levels.

Learners with Proficiency Gain: Engagement with English. Learners 1, 3, and 5 increased their English proficiency score by 100 points. Table 7 reports excerpts of responses by the three learners. As can be read in Table 7, all three learners were consciously engaging in English, for example, by studying, speaking, and reading. These learners also tend to be positive about their life abroad.

Table 7. Data Reduction (three learners who had higher CASEC scores after language training – by more than 100 points).

Learner	CASEC Pre	CASEC Post	Interview responses (post-return)
Learner 1	420	595	"I studied really hard everyday…I spoke a lot of English with Koreans in the dorm."
Learner 3	330	435	"Every day was meaningful… Each day was filled with a lot of contents."
Learner 5	330	475	"I read aloud a lot, and my teachers told me my speaking got faster."

Learners with Increase in Willingness to Communicate Levels: Real-Life Conversations and Intensive Speaking Practice. Learners 6, 8, and 17 developed their willingness to communicate levels. Table 8 shows responses by these learners. As can be read in Table 8, learners became comfortable being spoken to in English, and were not hesitant to speak. Authentic speaking practice opportunity through real-life conversation and one-to-one lessons helped learners to be more proactive in communication, and as a result, fostered willingness to communicate.

Table 8. Data Reduction (three learners who had higher willingness to communicate levels after language training).

Learner	WTC Pre	WTC Post	Interview responses (post-return)
Learner 6	0.48	0.88	"I am used to people starting conversation to me in English… At the shops, I am not surprised and I can just talk."
Learner 8	0.40	0.73	"At first, I didn't want to make mistakes, so I wasn't speaking much. But, later, I didn't care about mistakes. Since there were a lot of one-to-one lessons, I began to speak a lot."
Learner 17	0.13	0.75	"I used to never start a conversation. Also, if I didn't understand, I never asked. But, I could ask now…I don't care about mistakes anymore."

Learners with Increase in Motivation Levels: English as a Lingua Franca and NNS-NNS Interaction. As can be seen in Table 9, learners 9, 19, and 20 increased their motivation score, and they were inspired and motivated by interacting with Filipino instructors who learned English as a second language. In addition, the fact that many Filipinos were speaking English as a lingua franca on the streets and at the shops was a stimulating and a motivating factor.

Table 9. Data reduction (six learners who had higher motivation after language training).

Learner	Motivation Pre	Motivation Post	Interview responses (post-return)
Learner 9	0.60	0.90	"The best part of the trip was one-to-one lesson… It was so much fun…The teacher was friendly so we talked about many things."
Learner 19	0.55	0.80	"Teachers spoke Tagalog as their native language, but they were all educated to use English as a second language. Teachers had studied English very hard."
Learner 20	0.50	0.90	"Not just teachers, but many people on the island were bilinguals. Many people were taught in English on this island."

Learners with Decrease in Language Anxiety Levels: Personalized One-To-One Communication. Learners 9, 14, and 17, among others, lowered anxiety after studying abroad. The interview responses shown in Table 10 indicate that learners felt less anxious after engaging and practicing speaking in one-to-one personalized interaction with the Filipino instructor.

Table 10. Data reduction (three learners who had lower anxiety after studying abroad - more than 0.50 points)

Learner	Anxiety Pre	Anxiety Post	Interview responses (post-return)
Learner 9	1.00	0.50	"My one-to-one teacher tried hard to understand my English, so I wasn't nervous anymore."
Learner 14	0.75	0.20	"The best part of the whole study abroad was the one-to-one lesson…It was so much fun and I wanted to do that more… My teacher worked on my pronunciation a lot… Everyone on the street was so friendly there."
Learner 17	1.00	0.20	"In Japan, I hated speaking in English…I hated talking to non-Japanese… But, I got used to it there, and really had fun talking to people from other countries."

4 Discussion

4.1 Discussion on Proficiency Gain

Research question one was to investigate learners' English proficiency gain by studying in English as a lingua franca environment for 5 weeks. The study found that learners made gains in their English proficiency.

The Philippines SA language training program may have provided a hybrid learning environment. In the Philippines, learners engaged in both classroom instruction and one-to-one instruction. Even though learners did not have opportunities to engage in natural social interactions at homestays, the combination of classroom and one-to-one interactions provided both formal and informal speaking practices. This may have created a hybrid environment which is believed to provide the best setting for learning a language, as mentioned previously in Sect. 1.1.

Even with the NNS-NNS combination of interaction, the Philippines SA program simply promoted intensive language use for Japanese learners of English through one-to-one and classroom instruction. As reported previously in Sect. 1.1, the description of the benefits of the various SA language learning contexts included an enormous amount of comprehensible input, as well as speaking practice for the learners, and getting a number of things done in the language they are learning. This study shows that SA language learning contexts do not have to be native speaker environments, as long as learners engage themselves in language use opportunities with NNS.

4.2 Discussion on Affective Factors

Research question two was to investigate if learners develop affective factors, i.e., willingness to communicate and motivation, and reduce language anxiety, by studying in English as a lingua franca environment for five weeks. From the reduced qualitative data based on the quantitative findings, the following is elucidated.

Willingness to Communicate. In terms of willingness to communicate, Japan is a monolingual country, and learners rarely have a chance to use English outside of classroom. Engaging learners with a lot of speaking practice during SA is an important aspect. Intensive speaking practice offered by one-to-one instruction and real-life authentic interaction fostered willingness to communicate in the Philippines. The significance of this study is measuring and reporting the increase in willingness to communicate in a non-native English environment after only five weeks.

Motivation. Learners of English in Japan have difficulty motivating themselves to study English, as they lack opportunities to use English out-of-class. Being in an environment where English is used as a lingua franca and having NNS-NNS interaction fosters motivation. Simões reports that a mere five-week-abroad experience resulted in higher levels of self-confidence and higher motivation in learners, as previously noted in Sect. 1.2. This study shows that five weeks in a non-native environment also resulted in higher levels of motivation, which is a new finding.

Language Anxiety. Research findings report Japanese university students to be shy. Klopt [27] compared communication anxiety by comparing university students in seven countries; America, Australia, Korea, China, Philippines, Micronesia, and Japan. Among the students surveyed, when communicating in their native language, Japanese participants had the highest communication anxiety. This suggests that Japanese tend to be less proactive and more passive in their own language. The implication of this shyness would naturally be difficulty in English communication. Personalized one-to-one instruction is less threatening for Japanese students who are shy, and learners who lack confidence in English communication skills. Also, having Filipino instructors may have reduced the apprehension of meeting the expectations of native-like perfection.

5 Conclusion

5.1 Strength and Limitation of this Research

There is a lack of research and documentation on the impact of SA in the Philippines. SA destinations where English is used as a lingua franca are also under researched. The aim of the present study was to fill these gaps by examining and documenting learning experience in the Philippines in the English as a lingua franca environment, and this aim itself is one of the strengths of this research.

The results of this study, however, have to be interpreted with caution as the generalizability of the study might be limited by the number of participants, their gender, and proficiency level. In case of this study, there were 21 females, and they were elementary to intermediate level of English proficiency.

5.2 Future Research

Implications are drawn for further research in accumulating more data from the SA context in the Philippines, in particular, analyzing the NNS-NNS learner-instructor interaction, and possibly the pedagogy of one-to-one and instructional lessons.

Finally, the focus of this study was to document the impact of SA experience in the Philippines by measuring the outcomes and exploring learner experiences. However, there are broader implications for future research. Investigating learners in multilingual and multicultural SA contexts will clarify needs and issues surrounding English education and intercultural education toward fostering intercultural communication skills that are needed in an increasingly globalized society.

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Agile for Newbies: A Scrum Workshop Design and Implementation Process

Julio C. Guzmán, Gustavo López(✉), and Brenda Aymerich

Research Center for Communication and Information Technologies, University of Costa Rica, 11501 San Pedro, San José, Costa Rica
{julio.guzman,gustavo.lopez_h, brenda.aymerich}@ucr.ac.cr

Abstract. "Scrum is simple to understand but difficult to master". This paper describes our efforts in designing and testing a 16-h Scrum workshop that provides an overview of Scrum´s core concepts. The workshop is intended for participants with little or no background on Scrum. Designed by four certified scrum masters, this workshop combines different practices gathered from a series of training and day to day applications of Scrum. We have tested and improved the workshop described in this paper in 5 iterations over the past two years. Feedback from participants and improvements proposed by instructors were incorporated. The workshop combines theoretical knowledge and practical activities to help participants interiorize the theory. The design of this workshop is modular so that it can be adapted to different participant´s needs. Activities are designed to be developed in workshops with 15 participants.

Keywords: Scrum · Agile training · Software development

1 Introduction

The software development industry is fierce. Nowadays, companies require to innovate and adapt their practices. Scrum, as a software development framework has proven its effectiveness in these conditions. Many companies around the world are trying to introduce agile, and Scrum principles in their processes. Therefore, they are training their personnel.

Due to a requirement from a partner company to train over 240 employees, we decided to create a workshop in which theory and practice are combined to achieve a deep understanding of agile and scrum principles, techniques, sessions, and instruments. The workshop is focused on the Scrum Master perspective (i.e., team facilitation, coaching, and impediments removal). Also, we designed another training for Product Owners in a side by side and coexisting effort.

This paper describes our efforts in designing and testing a 16-h (two days) Scrum workshop that provides an overview of Scrum´s core concepts and evidence the context conditions that force companies to implement agile practices. The workshop is intended for participants with little or no background in Scrum. However, we have tested it with experienced participants and the results have been positive.

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The two-day training has four large timeboxes in which theory and activities are imparted. The first timebox combines ice-breaking activities with core theory (i.e., Agile Manifesto and Scrum Guide). This first timebox uses traditional education mechanisms such as association and completion of sentences. The most important lesson of this timebox is the value of iterative work, inspection, and adaptation. These lessons are gamified.

The second timebox focuses on the main problems solved using Scrum. Two group activities (involving all 15 participants) and one exemplification of these problems are used as educational methods.

In the second day, the third timebox describes the contexts in which agile practices are applicable, explained, and exemplified. Moreover, estimation techniques are introduced and practiced. This estimation will be also used in the last activity of the workshop.

The final timebox is called "applying what I learned," and it is a continuation of the estimation done in the third timebox. This last section of the workshop replicates an iterative construction of a product using a series of user stories previously defined, estimated and prioritized.

The workshop described in this paper was conducted with five different groups of 15 participants during the past two years. Feedback from participants and improvements proposed by instructors were incorporated. We only describe the final version of the workshop, but the paper also includes lessons learned from the design and grooming process.

2 Workshop Design

The workshop described in this paper was designed iteratively. From the first version of the workshop, five implementations provided feedback and improvement opportunities. At the end of each implementation, trainees evaluated the workshop, and we adapted the materials and contents accordingly.

The materials of the workshop were a handbook and a workbook. The handbook condenses all the theory taught in the workshop. There, we describe Scrum events with their respective goals and timeboxes (e.g., Sprint Planning, Daily Scrum, Sprint Review, Sprint Retrospective, and Sprint Grooming).

Furthermore, Scrum Roles with their respective characteristics and responsibilities are described (e.g., Scrum Team, Scrum Master, Scrum Product Owner, Development Team, and Stakeholders), Scrum artifacts (e.g., Product Backlog, Sprint Backlog, product increment, and the Definition of Done). Finally, the handbook explains Scrum fundaments, user stories, burn-down-chart, Cynefin Framework and some useful tips.

The workbook is a tool used by the trainees in some activities during the workshop. Trainees can find the agenda for the two days, visual material, activities, instructions, and some extra pages for notes. Each trainer has their way to teach, and the trainer must guide trainees through the workbook, clear doubts and explain the goal and lesson of each activity.

During the workshop, each activity is a mix of theory and practice using the gamification as a learning method. Mandatory attendance is required to complete the training.

2.1 Collaborators

Five Certified Scrum Masters designed the workshop described in this paper. The first Scrum Master is a project manager with more than 12 years of experience. Before becoming a project manager, he was a full-time professor at a university in the department of Computer Science. He holds a Certified Scrum Master (CSM), a Certified Scrum Product Owner (CSPO), and a Certified Scrum Professional (CSP) certifications from the Scrum Alliance. Furthermore, he holds a Project Management Professional Certification (PMP).

The second Scrum Master is a senior software engineer and professional developer. He has extensive management experience and has been the lead developer of different projects for the past 20 years. He holds the CSM and CSPO certifications.

The third Scrum Master is a professional in computer science with two years of experience. He holds a CSM certification. Moreover, he has worked as in IT support for the past 10 years. The fourth Scrum Master is a researcher with three years of experience. She holds a CSM and CSPO certifications.

Finally, the fifth Scrum Master is a full-time researcher and professor at a University. He holds a CSM and CSPO certifications. Moreover, he has 5 years of experience as an agile consultor and seven years of experience as a professor.

2.2 Topics, Timeboxes and Activities

The first timebox of the day focuses on the value of iterative work, inspection, and adaptation. We started address trainee's doubts, for that we used a *Parking Lot* space. The concept of a parking lot refers to a question that needs to be parked (saved) until the end of the presentation or activity.

First day, in the all trainees get together in a daily standup meeting where all the participants respond three questions: What is my name? What did I do yesterday? What are my expectations of the workshop? This exercise allows the trainer to introduce one session of Scrum and to learn about participants.

Our socialization activity is a clock. Each participant is provided with a drawing of a *date clock,* and they have to arrange six meetings with other participants. Each date corresponds to a coffee break or lunch.

In the second timebox, trainers explain theory including the Agile Manifesto, Scrum Roles, Scrum events, Scrum artifacts, and the value of iterative work. With all this knowledge in mind, trainees participate in the *styrofoam balls scrum simulation*. In this activity trainees create a circle; they try to pass the maximum number of little styrofoam balls hand-by-hand in one minute and thirty seconds. To pass a ball, each participant must drop the ball at shoulder height, and the next participant receives the ball at the height of the hip. Before participants start, they must estimate how many balls will go around the circle. After each sprint, trainees have one minute to make retrospective, evaluate the context and adapt their practices to achieve a better result. This activity is conducted in three sprints and it is a variation of the ball point game [1].

In the third timebox, trainers introduce concepts as empiricism, the complexity of group collaboration, product vision, and minimum viable product (MVP).

To exemplify the complexity of group collaboration and communication an activity called *communication lines* is used. In this activity, a group passes a thread between them until everyone is connected to each other. Then a group of eight performs the same activity. This exercise allows participants to understand that large groups are not able to communicate effectively. Empiricism and MVP are described using examples.

In the last timebox, trainees complete one activity where they learn the value of *teamwork*. In groups, they must travel an obstacle course using one marker and cardboard with threads as Fig. 2 shows. The instructions are straightforward, in silent; every trainee must hold one thread from the end, and they have three minutes for complete the track. Every time, the line drawn by the marker gets out of the track or bump an obstacle, the team must start again. This activity is a variation of the team drawer game [2].

The end of the first day is another daily standup meeting. In this case, trainees provide feedback of the day. They answer: What is your key takeaway from this day? What are you going to do with the knowledge you gained? Which impediments do you foresee to apply Scrum in your context?

The second day starts with the trainer's answers doubts stick in the Parking Lot. Then, trainees review and update their team's rules. Also, Cynefin is explained, and one activity is conducted (Fig. 1).

In the *Cynefin* activity, participants are asked to simulate contexts. To exemplify the simple/obvious context participants are arranged in a straight line, and they are asked to raise their right hand sequentially. This exercise is a simple exercise that provides evidence of a "follow instructions" scenario. To exemplify the complicated context participants are asked to arrange themselves in order by height. In this activity, they use the practice they want possibly following "good practices". In the complex scenario each participant is asked to triangulate their position in a room with other two participants without them knowing. We give them 5 min to try and create perfect equilateral triangles. In this exercise, they move randomly, and every movement has a repercussion in the system. The final context (chaotic) is not simulated since it would require an emergency scenario.

The morning continues with the Pareto Principle, estimation techniques, and the fallacy of multi-tasking. The *fallacy of multi-tasking* is explained using a dynamic activity. First, trainees in pairs are asked to sing a famous song (one word at a time intercalated) the time of this activity is recorded. Then participants are asked to play a hand game and the time is also recorded. Finally, participants are asked to count from one to ten interleaved and the time is recorded. Then these three activities are conducted simultaneously; participants have to switch from one to another when the trainer gives them a cue. When they return to a previous activity, participants have to recall their status and continue from there.

The third timebox of the second day starts with the *penny game* [3].

Then an activity called "Applying what I learned" is conducted. The objective of this activity is condensing estimation, prioritization, and an iterative work. The idea of

Day	Time	Activity
Day 1	8 am - 9 am	Logistics, introductions and team selection
		Socialization activity (Date clock)
		Daily Standup
	9:15 am - 12 md	Theory
		Styrofoam balls scrum simulation
	1 pm - 3 pm	Theory
		Communication lines
		Agile planning
	3:15 pm - 4 pm	Teamwork
		Daily Standup
Day 2	8 am - 9 am	Learning review
		Cynefin
	9:15 am - 12 md	Theory
		Multitasking falacy
	1 pm - 3 pm	Penny Game
		Applying what I learned
	3:15 pm - 4 pm	Closing

Fig. 1. Workshop schedule

the activity is simulate the creation of one Recreation Center. The trainees, in their groups, receive a set of user histories. First, they should estimate the effort required for each user history using an estimation technique. Then, they receive the priority given by the Product Owner, in this case, the trainer. They have 7 min for planning, 15 min to build the product, 4 min of review with the Product Owner, and 3 min for retrospective, this along 3 iterations. All the user histories are described in the Table 1.

The priority in the first iteration for the user histories is Recreation Center Name, Logo, Chromatic Palette, Slogan, Souvenir, Domain Name, Waiting Call, Restaurants Identity, Video, Agenda, Brochure, Map, and Intern Transport.

It is important to notice that user histories Isotype, Imagotype, and Restaurants Identity are not part of this iteration. It is because stories Logo and Restaurants Identity are traps. Most of the trainees make a draw in the Logo user story. That is a mistake because a Logo is an identifying symbol, not a draw. Also, the Restaurants Identity is an epic user story, and the team should try to negotiate that user story with the Product Owner.

After the first iteration, the priorities changes, also changing the scope of some teams. The new priority for the second and third iteration is Name, Logo, Chromatic Palette, Slogan, Souvenir, Domain Name, Waiting Call, Video, Agenda, Brochure,

Table 1. User Stories developed in the activity "Applying what I learned".

Name	User story
Recreation center name	As a Marketing Manager, I want a name for the recreation center, so that create identity for the place
Logo	As a Marketing Manager, I want a Logo for the recreation center, so that create identity for the place
Slogan	As a Marketing Manager, I want a Slogan for the recreation center, so that catch the attention of the visitants
Chromatic palette	As a Marketing Manager, I want to define the colors of the recreation center, so that can be use in all the advertising material
Domain name	As a Community Manager, I want a Domain name for the recreation center website, so that allow visitants go to the site
Map	As a Marketing Manager, I want a Map for the recreation center, so that allows the designers add the map into the website
Video	As a Marketing Manager, I want a Video for the recreation center, so that allows the marketing's teams promote the center
Brochure	As a Marketing Manager, I want a Brochure for the recreation center, so that the distribution of information to potential visitants
Waiting call	As a Reception Manager, I want an audio, so that can be the waiting call
Intern transport design	As a Marketing Manager, I want the design of the intern vehicle of the recreation center, so that allows create an association between the transport and the recreation center
Restaurants identity	As an Entertainment manager, I want the design for three restaurants, so that opens the eating options of the visitant and create an integral identity of them
Agenda	As an Entertainment manager, I want the activities agenda for the weekend, so that opens the entertain options of the visitant
Isotype and Imagotype	As a Marketing Manager, I want an Isotype and an Imagotype for the recreation center, so that catch the attention of the visitants
Souvenir	As a Marketing Manager, I want a Souvenir for the recreation center, so that will be a gift to promote the recreation center

Map, Intern Transport, Italian Restaurant Identity, Japanese Restaurant Identity, Meat Restaurant Identity, Isotype and, an Imagotype. In these iterations, Product Owner add new user stories in order to help the trainees throw the activity.

That change helps trainees to understand the possibility of changing the scope of a project and how Scrum allows changes in the plans. The activity ends with a general review where a team shows their products to the rest of the trainees.

The design of this workshop is modular (i.e., it can be easily changed depending on the participant needs). Activities are designed to be developed with 15 participants and a high degree of rotation in enforced.

3 Implementation

Two implementations of 15 people each were conducted in November 2016, 15 people were trained in December 2017 and other two implementations were conducted in January 2018 (i.e., 75 participants in total). Figure 2 shows some pictures of the main activities conducted in the workshop.

Fig. 2. Activities performed during the workshop.

3.1 Trainers Profile

This workshop can be imparted by Certified Scrum Masters who combines different practices gathered from a series of training and day to day applications of Scrum. It is required have experience teaching and explaining the benefits of agile. Trainers use the workshop as material support. The workshop combines theoretical knowledge and practical activities to help participants interiorize the theory. So the trainer is a dynamic person who can attract the attention of the participants through the entire workshop.

3.2 Trainees Profile

Trainee's profiles are diverse. We can say most everybody can take the workshop. Usually, our trainees' work is related to IT departments, which includes developing software, project managers, business strategies, human resources, QA, and others. All trainees come from the same large multi-industry state-owned company.

Participants in all the implementations of the training had little or no experience with Scrum. However, some participants had background in project management.

4 Findings and Discussion

In most cases, others trainers used more than two days to teach agile framework. It is normal to try to teach Scrum in a software engineering course [4] or at least in a week [5]. Our approach was condensing all what a potential Scrum Master needs to know using a gamification technique. Even though some trainees express their desire to participate in longer workshops, we understand how difficult is for many workers participate in a workshop for two days and the impact on their company.

We applied an iterative perspective to improve. The first time we impart the workshop, we count with 30 trainees split into two groups. One month after, we made a retrospective session with all participants using the agile principle of inspection. The trainees expressed some disappoint because the workshop was too theoretical. So, we took the findings and redesigned the workshop repeating the process. The second time that we gave the workshop to another to other group of 30 trainees, the result was very dynamic but unbalanced, so it was necessary to increase the theoretical base. One more time, we made a retrospective to raise the level of the workshop.

The third and fourth time we teach the course, it was a resounding success. In this paper, we only describe the final version of the workshop, but all the learned lessons for us were valuable.

We aimed to create a workshop where the theory and practice come together using gamification as a standard base. Consequently, best strategy for us was found the correct balance to warranty the best exploitation by part of the trainees.

5 Conclusions

The workshop is proof itself of the effectiveness of iterative work. It would not have been possible to perform without the feedback of the trainees.

The use of agile frameworks, as Scrum, demands a cultural change that is not always easy to accomplish. Here is where gamification is useful to break the traditional teaching way and trying to change the culture too. Also, the type of activities requires trainees' participation, so that minimize the resistance to learn, especially when all trainees work together.

As we said in the trainees' profile, software engineer background is not a requirement, neither in agile nor Scrum to participate in the workshop, and this makes it possible have types of trainees enriching the discussion. When the trainees came from different areas, the debates were better and more in-depth about how to apply Scrum.

Few trainees came with expertise in agile frameworks, but their expectative were surpassed what allowed them to discover new dimensions of the agile framework. Moreover, the expectations of the trainees in the usage of Scrum in their jobs context change after they participate the workshop. We genuinely believe in this methodology of teaching, and we want to continue inspecting and adapting this workshop for the sake of improving. We have another workshop, develop with the same strategy, for the Scrum role of Product Owner, work that will be present in future investigations.

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The Management of Occupational Health and Safety in Vocational Education and Training

Sari Tappura[1(✉)], Anna-Maria Teperi[2], Anna-Leena Kurki[2], and Jouni Kivistö-Rahnasto[1]

[1] Center for Safety Management and Engineering, Industrial and Information Management, Tampere University of Technology, P.O. Box 541, 33101 Tampere, Finland
sari.tappura@tut.fi

[2] Safety Solutions, Finnish Institute of Occupational Health, Työterveyslaitos, P.O. Box 40, 00032 Helsinki, Finland

Abstract. Vocational education and training (VET) providers must provide a safe and healthy learning and working environment for their students and employees. Establishing a culture with effective occupational health and safety (OHS) procedures helps VET providers in meeting this duty of care. The objective of this study was to describe the practices of sustainable OHS management in VET. The procedures were studied in six VET provider organizations; 6 workshops were arranged and 58 employees were interviewed. The procedures revealed were categorized into preventative actions, actions during the incident, and actions after the incident. Prevention is possible when sustained proactive and reactive actions are directed at the individual, team, working environment, and organization levels. The results will guide VET and other organizations toward shaping OHS policies and safety culture in the field of education. Furthermore, developing safety culture may achieve other VET providers' goals, such as quality of education and student performance.

Keywords: Occupational health and safety · OHS management
Prevention · Safety culture · School safety

1 Introduction

In Finland, vocational education and training (VET) involves about 327 000 students and 45% of the youth age group annually [1]. It has been found that risk-taking behavior is established during youth and extends into adulthood [2], and that young workers experience the highest rate of occupational injuries out of any age group [3]. Incorporating occupational health and safety (OHS) issues into VET might reduce work-related injuries and ill-health among young workers. Prevention is possible when sustained actions are directed at team, individual, organization, and learning and working environment levels [4]. Moreover, students benefit from increased OHS awareness when they enter working life.

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In Finland in 2018, there are 149 VET providers owned by a municipal federation, municipality, private company, or the state [5]. Based on the education and OHS regulations, VET providers must run a safe and healthy learning and working environment [6, 7]. Establishing an OHS culture with effective OHS processes helps in meeting this duty of care for their students and employees [8–10]. Hence, OHS issues are management's responsibility in VET provider organizations. OHS issues can be integrated into existing management processes and development rather than being addressed through separate procedures [4, 11–13].

VET providers operate under the Finnish OHS regulations [6] including activity in relation to work done by students in connection with their education, if that work is done under a VET provider's direction. The OHS requirements are quite demanding for general vocational teachers who direct and supervise on-the-job learning. VET providers and teachers need information and guidance in complying with the OHS requirements and in ensuring the occupational safety of the students during on-the-job learning in vocational education [14, 15].

Currently, VET providers are facing major challenges due to digitalization, economic pressures, vocational educational reform, and a decrease in the number of students among future age groups [7, 16]. Among other challenges, VET providers, along with their employees and students, should be supported in both proactively and reactively handling OHS risks. In Finnish VET provider organizations, OHS is traditionally developed via projects with limited resources and competence and is mainly viewed from students' perspective during on-the-job learning [14, 15, 17]. However, the systematic development of both students' and employees' OHS is the VET providers' responsibility.

Understanding the current safety culture of the organization (here, the VET providers) is an essential prerequisite for improving OHS activities. Safety culture has been characterized as a set of often unconscious thinking patterns, basic assumptions, beliefs, and values that guide operations and ultimately determine how people act at work and whether their working practices support or compromise safety [18, 19]. Most definitions consider safety culture to be the part of organizational culture that focuses on safety [19, 20].

In relation to safety culture, management commitment to OHS needs to be emphasized [2, 12]. Managers' commitment to OHS arises from increased awareness, which may be induced reactively by an accident or other crisis, or proactively by a training or OHS improvement program [21]. Managers at different organizational levels (strategic, tactical, and operational) can support the behaviors and activities of their students and employees through their own actions [22]. This, in turn, can improve the safety and wellbeing of both the students and employees.

VET provider organizations (including their managers, employees, and students) have to be able to manage disturbances and adapt their actions to varying circumstances to control OHS risks. Thus, safety is based on their ability to respond to situations that are not what they expected; to cope with situations that have become critical; to anticipate disruptions and their potential consequences; and to learn from these experiences. This is the focus of recent new safety paradigms, resilience engineering, and Safety-II thinking, which emphasize the resources of individuals, teams and organizations [23–25] for both proactively and reactively handling safety risks [26, 27].

Here, common and jointly shared organizational OHS practices are key measures for proactively managing safety in VET provider organizations.

OHS issues are addressed inadequately in current school safety models [8, 9]. Establishing a positive safety culture with effective OHS management practices helps VET provider organizations to meet their duty of care [10]. Hence, OHS issues cannot be put aside since they are a core issue in vocational education. Furthermore, developing safety culture and OHS may achieve other VET providers' goals, such as quality of education and student performance [9, 10].

2 Materials and Methods

The objective of this study was to describe the typical practices of sustainable and preventative OHS management in VET provider organizations. The study employed a qualitative approach [28] due to its descriptive and contextual nature. Information about the practices were studied between 2016 and 2017 in 6 Finnish VET provider organizations where a total of 58 employees were interviewed (see Table 1).

Table 1. Background information about the interviewees (n = 58).

VET provider	Number of personnel (2016)	Number of interviewees
1	700	8
2	760	10
3	460	11
4	860	9
5	650	10
6	300	10

The employees interviewed represented different personnel groups (such as managers, teachers, and support services personnel, including student, catering, cleaning, ICT, and maintenance services personnel) with 29 female and 29 male interviewees (see Table 2). Interviews have been regarded as a valid instrument for evaluating safety culture; this is because safety culture cannot be studied merely by quantitative methods as these cannot perceive the conceptions behind actions [18, 19].

In addition to the interviews, six workshops were arranged where OHS professionals of the participating organizations (such as safety manager, head of OHS, and OHS delegate) were involved. The OHS management practices revealed from the interviews and workshops were categorized into three classes according to Teperi & Puro [29]: (1) before incident situation (preventative actions); (2) during incident situation (to respond to situations); and (3) after incident situation (to cope with situations).

Table 2. Background information about interviewees' occupations (n = 58).

Occupation	Number of interviewees
Principal or deputy principal	2
Sector manager	2
Development manager	1
Training manager	4
Team leader (teaching)	4
Teacher, lecturer, or trainer	26
Support services manager	8
Support services personnel	11

3 Results

According to the interviews in the six VET provider organizations, the employees acknowledged the OHS management practices they could identify. The most familiar practices to the interviewees were the practices they participated in regularly, such as evacuation exercises and safety walks. The interview results were categorized based on how OHS is managed proactively as well as during and after incident situations. Table 3 presents examples of preventative actions. Both employees and students participate in the OHS practices, but the VET provider's personnel have a directive role over the students in most of the practices (such as risk assessments, safety walks, and OHS exercises).

Table 3. Examples of preventative actions in VET provider organizations.

Category	Purpose	Examples of OHS practices
Before incident situation	To prepare preventative actions to situations	OHS management system
		OHS activity plan
		Occupational health care plan
		Definition of OHS responsibilities
		Top management safety group
		Safety groups of the campus or building
		Safety folder and instructions
		Risk assessments
		Rescue plans
		OHS introduction
		Introduction of external actors

(*continued*)

Table 3. (*continued*)

Category	Purpose	Examples of OHS practices
		Regular evacuation exercises
		OHS training
		First aid training
		Training for threatening situations
		Chemicals register and safety data sheet folder
		Machine safety instructions
		Safety notices and near-miss reports processing
		Internal fire-safety inspections
		Elmeri + workplace observation method
		5S workplace organization method
		Construction site safety audits
		OHS audits
		Safety walks
		Workplace surveys
		Procedure for indoor air problem resolution
		Procedure for psychosocial risk control
		Procedure for threatening and violent situations
		Early support procedure
		Rules for appropriate work behavior
		Well-being development workshops
		Stress analysis and control workshops
		OHS campaigns and themes in communication

The persons responsible for campus or building safety and particular safety teams were typically nominated in VET provider organizations and were well known. OHS training, such as OHS introduction, occupational safety card training, first aid training, and training for threatening situations was in place in the organizations studied. They had procedures and regular exercises for different kinds of incident situations, such as fire, sudden illness, chemical accident, or school attack. In addition, they had a variety of audits, walks, and observations in use to monitor the safety of the learning and working environment and to carry out preventative actions against the revealed OHS risks. For example, the regular checking of fire extinguisher and first aid equipment was part of the monitoring process. For the management of mental OHS risks, they had such procedures as early support and psychosocial risk control procedures, stress control and well-being development workshops, and rules for appropriate work behavior. One organization had a certified OHSAS management system.

Table 4 shows examples of the practices to respond to incident situations. The VET provider organizations studied had both fixed (traditional) and mobile alarm systems in use to warn and evacuate people in case of an emergency. They also had technical solutions, such as electrical locking of entrance doors. Some employees at high risk (such as welfare officers) had panic buttons in their rooms or mobile systems to call for help in dangerous situations. Available and operational emergency equipment, such as firefighting and first aid equipment, were seen as important during incident situations.

Table 4. Examples of practices to respond to incident situations in VET provider organizations.

Category	Purpose	Examples of OHS practices
During incident situation	To respond to situation	Persons responsible for campus or building safety
		Alarm systems (fixed or mobile)
		Panic buttons (fixed or mobile)
		Electrical locking of entrance doors
		Evacuation charts
		Firefighting equipment
		First aid equipment and personnel
		Chemical information and first aid equipment

In Table 5, examples of practices to cope with the incident situation are presented. VET provider organizations reported and analyzed injury and dangerous situations data and took corrective actions based on that information. They had a crisis group, welfare group, or similar, where the dangerous or difficult situations were handled and discussed confidentially. Many interviewees also mentioned supervisor or peer support as

Table 5. Examples of practices to cope with incident situations in VET provider organizations.

Category	Purpose	Examples of OHS practices
After incident situation	To cope with situation	Injury reporting and analysis
		Dangerous situations reporting and analysis
		Corrective and preventative actions
		Crisis group
		Support discussions with supervisor, peers, or occupational health care professionals
		Handling in a department meeting

important in coping with incident situations. Students have their own welfare services to support them in difficult situations.

In VET provider organizations, the employees and students are regularly reminded of the OHS procedures and timely action in workplace meetings, info sessions, and media. Moreover, the organizations participate in national OHS campaigns and utilize related info material as a part of their OHS management.

4 Discussion

The current study aimed to emphasize effective OHS management practices in helping VET provider organizations to meet their OHS management responsibilities and their duty of care for their students and employees [10]. Moreover, the study aimed to emphasize OHS issues in relation to current school safety models [9].

This study described a three-class categorization of OHS management practices in Finnish VET provider organizations. The categorization is based on Teperi & Puro's study [29] and includes preventative actions as well as procedures to respond to incident situations and to cope with incident situations.

In the VET provider organizations studied, the focus was on preventative actions, and various preventative actions were in use. Training and practicing are important in maintaining the ability to act in case of an emergency and in safety becoming a day-to-day routine. Moreover, the prevention focus and proactive approach are also important in increasing the visibility and feeling of safety. During incident situations, the roles and responsibilities of all employees should be clear and the emergency equipment available and in operation. After the incident situation, it is important to facilitate understanding of the situation and encourage employees' adaptive coping [29].

The VET provider organizations studied had a large variety of OHS management practices in use, and their implementation varied a lot (see also [9]). The same was found in a study of Finnish elementary school safety management practices [23]. It is known that defined procedures are not necessarily followed in reality, and even good practices can be hidden away, or commitment to their implementation may be eroded over time [4, 13]. Moreover, in some VET provider organizations, the OHS practices were somewhat disconnected, and the overall picture of OHS management was somewhat unclear (see also [9]).

Based on this and earlier studies [4], prevention is possible when sustained actions are directed at the individual, team, working environment, and organization levels, while all these may contribute to risks and incidents and inhibit personnel from succeeding in maintain safety at work. Therefore, information about sustained OHS management practices needs to be disseminated among VET providers. Moreover, students benefit from increased OHS awareness and competence when they enter working life and thus, can proceed good safety culture in their forthcoming work places. Students might also be used as a resource in VET provider's safety culture improvement while VET providers may have limited resources to implement all OHS management procedures proactively as well as during and after incident situations; students could be committed to joint safety improvement at VET organizations (see also [30]).

The scientific contribution of this study is based on its explorative nature. The categorization is based on previous studies on maritime [29] and is complemented with new empirical data from VET. Information was provided on the organizational measures to promote OHS in the educational sector. The practical contribution of the research is the information concerning the OHS management practices being used by VET providers. OHS issues are inadequately addressed in current school safety models [8, 9] and VET has not as long tradition in OHS management as for example industrial and transport systems which have done pioneering work with safety management systems [13, 30]. Moreover, safety culture is still developing within Finnish VET organizations and there is an important time frame going on to encourage favorable safety culture by offering clarifying models and procedures for the field. Therefore, information about favorable practices needs to be disseminated among both VET and other educational organizations. This kind of cooperation was planned during this study, while safety management and safety culture was simultaneously with this study studied also at ten other Finnish educational organizations, namely comprehensive schools [30].

The results modelled by using concrete three-class categorization model used in this study provide guidance for teachers, school managers, safety professionals, OHS representatives, and VET and other educational organizations toward shaping OHS policies and safety culture in the field of education.

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Incidents in Schools - Incident Analysis in Developing Safety Management

Eila Lindfors[1(✉)] and Anna-Maria Teperi[2]

[1] Department of Teacher Education, University of Turku, Rauma unit, Seminaarinkatu 1, 2600 Rauma, Finland
eila.lindfors@utu.fi

[2] Finnish Institute of Occupational Health, Helsinki, Finland
anna-maria.teperi@ttl.fi

Abstract. Safety is the main issue in a good learning environment. However, several changes challenge schools. The latest research explicate that all teachers are not committed to promote safety systemically as they do not have competence or procedures to promote safety at work. Very little is known about incidents and near-misses that happen at schools to be able to learn from these and manage the safety culture proactively. This paper considers incidents, near-misses and unintentional accidents at school by analyzing 168 incident reports from three comprehensive schools in Finland, using physical dimension of safety management as a framework. The thematic content analysis made it possible to construct a clear 'big picture' of incidents in schools, and to better understand the complex context of school. The result helps researchers, principals, teachers and administration in education to consider physical hazards and risks and prevent accidents in school and in the school environment.

Keywords: Incident analysis · Near-miss case · Safety management
School safety · Proactive learning

1 Introduction

Safety in its various forms is a main issue for students and parents in Finland when considering a good learning environment [1]. Safety and security are norms that schools should guarantee for students and staff on the basis of the Finnish Basic Education Act [2]. It is known that changes in society challenge schools too. These safety challenges are for example accidents and incidents, like school fires, bullying, various kinds of near-miss cases, unintentional injuries, and even school shootings. The latest National Core Curriculum for Basic Education 2014 [3] in Finland points out safety procedures for learning environments a lot more than the previous one. A learning environment is seen a place, space, community and/or culture for learning that includes tools, materials, equipment and services, like school building, classes, schoolyard, sport fields, trips, visits. Safety culture of schools is understood as collaborative actions of staff and students as well as implementation of procedures that develop and promote safe and secure learning and working environment. All members of school, as an organisation,

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have to understand the importance of their active roles in promoting safety on the basis of their responsibilities. Staff members have to develop their safety competence in order to handle safety and security as a part of school practice but also to be able to carry out curriculum based safety education that promotes safety competence of students and integrates them as factors of school safety [comp. 4, 5]. It is not enough to handle the safety culture at hand in schools. The educational target is to develop students' safety competence for the future and this makes schools exceptional compared to other organizations.

Based on the earlier research it is very well known that proactive efforts and procedures that aim at promoting safety in an organization develop safety culture in practice [6]. Principals and teachers have forever tried to organise learning in learning environments as best as they can. However, the latest research on safety culture of schools explicates that all teachers are not committed to promote safety systemically [7]. They have neither competence nor procedures to consider and promote safety at their work [4]. On the basis of the earlier research we know that every fourth 8^{th} and 9^{th} grade student visited the school nurse during years 2010–2012 because of an accident at school [7]. Based on statistics the most unintentional accidents happened in Sports and during breaks [8]. In every fourth school there were hazards and risks that should have been solved with proactive procedures. However, these were left unsolved. [9] According to Reason [10] many near-miss cases and accidents might indicate a low safety culture. However, if there are no incidents reported it usually indicates that incidents are not recognized at all.

It seems obvious that we know too little about incidents and near-miss cases that happen at schools to be able to learn from these and manage the safety culture proactively. The incidents and near-miss cases are not systematically recorded, reported or monitored at schools, although open reporting of incidents is regarded as a core prerequisite of safety management already for a while [11]. This has to do with safety management at schools – while corrective actions and proactive learning are not possible if the reports are not made visible and handled at the school organizations. One generally used way to model risks at work environments has been to categorise them according to their severity from no-harm to minor and major incidents, in order to introduce relevant safety measures and to target new safety initiatives. This has originally been described at industrial settings for example by the principle of the Heinrich ratio [12], but later also criticized as a too stable model to assess safety improvements [13].

Safety and security in a learning environment can be considered in physical, social, psychological and pedagogical dimensions. The physical dimension is spaces and facilities with tools, materials, machines and equipment as well as the condition of them. The social dimension is about socially acknowledged values, attitudes and behavior and actions based on them. Psychological dimension includes personal values, attitudes, personality, motivation, knowledge and skills as well as experiences that are the basis for individual actions. The pedagogical dimension is about organization of teaching and the content and organisation of learning opportunities, participation, affection, rules, justice, responsibilities and peer support [14]. The space and equipment can be safe but without understanding about proactive actions it can be an unsafe and hazardous learning environment [4].

According to Maurino evolution of safety management systems (SMS) have three origins and interventions: First, system safety and engineering care for designing safety into the (technical) system, second, Human Factors (HF) optimises the people and the operational environment, and third, business management is needed, to ‘give sense to safety dollar’, and to have positive inputs from investing on safety. Integration of these three fields forms a discipline of safety management, which is operationalized as a SMS of the organization. The basic idea is that the management of safety is a standard organizational process and as a part of overall management and leadership. Organizational awareness and learning are essential, to understand and be aware of drifts towards failure. Thus, safety data, for example reported incidents, is essential, to be utilized as a part of strategic decision-making [15]. The new safety paradigm emphasizes resilience and understanding human factors behind the incidents [16–18].

This paper considers incidents, near-miss and unintentional accidents at school from a safety management point of view. The research question is: what kind of incidents - accidents and near-miss cases - happen at schools? The data, 168 incident reports is gathered from three comprehensive schools in Finland. There are no previous examples though some preliminary results from this data is reported [E.g. 19, 20]. The theoretical frame is safety culture with physical, psychological, social and pedagogical dimensions as basis for safety management [14].

2 Materials and Methods

2.1 Data and Study Context

This article discusses the safety management in primary and secondary education based on the analysis of incidents. Accidents and near-miss cases, altogether 168 incidents, were reported in three comprehensive schools by teachers and principals. A school safety tool, Green Cross [21], was used in reporting. The Green Cross is a digital application to be used in a quick documentation to make it easy for school staff, teachers and principals, to report incidents as a part of everyday practice at schools. It is not an application that teachers and principals would use normally as a daily practice. The application was offered to schools for use as a part of Safe school and EduSafe – research and development projects [22]. On a school level it is possible to see all the reported incidents in a monthly view (Fig. 1).

While reporting, the staff signed into the Green Cross application system and made a short written description of an accident or a near-miss case. As a part of safety culture, a school safety team or staff responsible for safety had the possibility to analyze reports and make actions and alterations needed in order to reduce future accidents at their school. However, they did not make any wider or deeper analysis of separate incidents.

The three schools in the study represent a comprehensive school with elementary and lower secondary education in grades one to nine (from 7 to 16 years old students). In the two schools there is also a pre-school (6 years old children). In the school I the amount of staff is 110 and students 940. In the school II the amount of staff is 40 and students 370. In the school III the amount of staff is 140 and students 1050. Two of the schools represent multicultural city schools and one is a town school with mainly Finnish

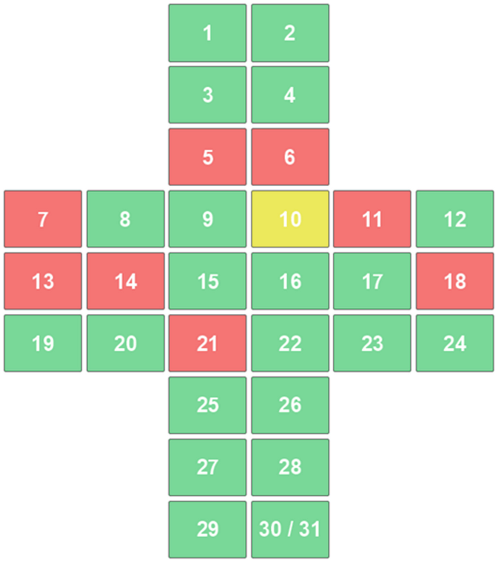

Fig. 1. A monthly view of reported incidents on a school level – Green Cross: School II, October 2016. Green day is a day without reported incidents, yellow is a near-miss case day and a red one tells about accidents.

origin students. The schools organize training for student teachers and for this reason the staff in each school is familiar with research and development projects.

The reports were downloaded into Green Cross application system by school staff during years 2016–2017. The motivation for the schools to participate in the study arose from a need to improve their safety culture and safety management.

2.2 The Analysis

In this study 168 reports were analyzed by qualitative thematic content analysis to understand what kind of near-miss cases and accidents happen at schools. The reports were written mainly in Finnish. The incidents from the reports were collected to a table and coded: a near-miss case or an accident and the school. For example, the incident tagged to the code II/32-NM tells that the incident is report 32 from school II, a near-miss case (Table 1).

The objective was not to compare the schools and incidents. The objective was to organize the incidents under the themes of theory-driven understanding of learning environment that considers safety and security at school from physical, psychological, social and pedagogical perspective (Lindfors 2012). The method was content analysis that was used to be able to make replicable and valid inferences by coding and interpreting the incidents. After several readings the incidents were organized under the themes. The lower and upper categories were formed under the themes through careful consideration of all the incidents. During this process several incidents were reconsidered and moved to category that fitted better. After all lower and upper categories were

Table 1. Risks and incidents in physical learning environments in primary and lower secondary education in comprehensive schools: I–III = school, number of the incident, MA = minor accident, NM = near-miss incident.

Incident	*Authentic example of an incident in categorization*	*Lower category*	*Upper category*	*Main category*
I/29-NM	Collision at corridor	Falling incidents at hallways and corridors	Falling risks and incidents inside school building	*Risks and incidents in physical learning environments*
III/10-NM	Stumbling on cables	Falling incidents with things/obstacles on/in wrong places		
II/10-NM	Pothole in the asphalt on the basketball court	Falling risks and accidents at Schoolyards	Risks and incidents at schoolyard	
I/52-MA	A slip at school yard	Winter slip pccidents		
II /8-MA	Drug squirts at schoolyard	Risks caused by people outside school		
II/11-MA	A stick in finger	Jungle gym incidents		
II/32-NM	Air conditioning in home economics does not work	Risks and incidents with air inside	Risks and incidents with non-functioning or broken facilities	
III/1-MA	A metal fishnet fall over a pupil	Incidents with broken facilities		
II/11-MA	An ankle sprain in the forest	Incidents at outside school learning environments: forest	Incidents at outside school learning environments	
III/13-MA	A biking accident on a school way	Traffic incidents on a school way	Incidents with traffic and parking	
II/9-NM	Bikers biking at a fast pace on the walkway from upper to lower yard	Near-miss cases with bicycles, cars tractors and parking		

finalized the main categories were formed and named (Table 1). These are (1) Risks and incidents in physical learning environments (28% of all incidents), (2) Risks and incidents in social learning environment (36%), (3) Risks and incidents in psychological learning environments (16%) and (4) Risks and incidents in pedagogical learning environments (20%). In this paper the category of Risks and incidents in physical learning environments is presented as an example to be able to discuss how incidents and incident analysis can be used in improving safety management.

3 Results

From all the reported incidents (N = 168) 20% were near-miss cases (n = 33) and 80% were accidents (n = 135). The seriousness of the accidents varied from light scratches, and/or bruises (minor accident = MA) to accidents in which students or teachers needed ambulance and doctor and hospital visits (serious accident = SA). The main category

Risks and incidents in physical learning environments consisted of 46 incidents. The main category was formed by five upper categories. These are (1) Falling risks and incidents inside school building, (2) Risks and incidents at schoolyard, (3) Risks and incidents with non-functioning or broken facilities, (4) Incidents at outside school learning environments and (5) Incidents with traffic and parking (Table 1).

3.1 Falling Risks and Incidents Inside School Building

Falling risks and incidents were recognized inside the school building. The upper category Falling risks and incidents inside school building was formed with two lower categories: Falling incidents in hallways and corridors and Falling incidents with things/obstacles on/in wrong places. While there were many people going and coming even running and playing in the corridors and hallways, there happened near-miss cases as well as collisions and fallings. Students had most of the collisions while teachers fell down while rushing to their lessons and meetings. The typical incident was a slip on the floor. The other falling incidents or near-miss cases were due to things and obstacles being in wrong places, e.g. electric cables, bags, chairs, open doors, like descripted in the report III/13-MA.

> *"The student from 8th grade stumbled on cables on the floor. The document camera fell down. Nobody was hurt."* II/10-NM.

Students and teachers had near-miss cases or stumbled and fell down while going around and jumping over things in classrooms as well as at hallways and corridors.

3.2 Risks and Incidents at Schoolyard

The second main category was Risks and incidents at schoolyard that was formed with four lower categories: Falling risks and accidents at Schoolyards, Winter slip accidents, Risks caused by people outside school and Jungle gym incidents. Falling risks and accidents at schoolyards were mostly due to varied potholes in the asphalt, playing yards and sport fields, stones or e.g. stumps.

> *"There are potholes at the end of the basketball court that is closest to the field. There are also some potholes near the white painted circle in the yard in the same area. There are many children playing basketball and there is a risk that they could twist their ankle by stepping in the holes as they are quite close to the basket and also the circle."* II/10-NM

The other lower category was Winter slip accidents. The report I/52-MA is a typical example.

> *"A slip at the schoolyard. A member of the staff fell down twice at the schoolyard while going home. Right knee and hand were hurt."* I/52-MA

The third lower category was Risks caused by people from outside school. While some people had used a schoolyard they had left hazardous things behind, like broken bottles and used drug syringes close to school. The fourth lower category was Jungle gym incidents. There were broken pieces of equipment that caused potential risks for users. The durability of equipment was lower because of the broken part or the surface was risky for hands.

3.3 Risks and Incidents with Non-functioning or Broken Facilities

The upper category Risks and incidents with non-functioning or broken facilities was divided into two lower categories: Risks and incidents with air inside and Incidents with broken facilities. Air inside problems were related unpleasant experiencers to dust, smells and air pressure at schools. Broken facilities were recognized as they caused some minor accidents for students and staff.

> *"The metal fishnet cover that keeps electrical buttons safe at the gym fell down over one student as the boll hit the cover. The student got a painful bruise." III/1-MA*

3.4 Incidents at Outside School Learning Environments

At outside school learning environments, there were reported several ankle sprains, allergic reaction and wounds. While there was a theme day, picnic or trip in forest or on a field students hurt themselves. This happened mostly in forests.

> *"A student from 8th grade hurt his ankle in the forest. Cold-treatment was first aid and it helped." II/11MA*

3.5 Incidents with Traffic and Parking

The fifth upper category was Incidents with traffic and parking. This was formed with two lower categories: Traffic incidents on a school way and Near-miss cases with bicycles, bikes, cars, tractors and parking. Traffic incidents were such as collision with a bicycle and a car without casualties or severe accidents. There were many near-miss cases with various vehicles were. The property caretaker caused hazards by driving tractor on the schoolyard during brakes. Students with bikes drove fast on their way home between students who were playing at schoolyard. Cars and bikes were about to crash. Cars that were parked against instructions caused hazards while students were running and cycling between them to the road. The report II/9-NM describes a typical near-miss case in the schools.

> *"When the school day ends some students who park their bike in the upper yard bike at a rapid pace down the walkway to the lower yard without concern for the children playing. There has been a few close calls where the bikers narrowly missed hitting a younger student. The younger children may not notice the fast paced bikers when running and playing and there is a risk of a collision and injury."* II/9-NM

4 Discussion

Instead of practice oriented consideration of incidents, the thematic content analysis made it possible to construct a clear 'big picture' of incidents in schools, and to better understand the complex and dynamic nature and context of school, which has been regarded as a prerequisite for supporting staff's work activities, and therefore tackling risks and improving safety [17]. The ultimate challenge during this study was to encourage teachers to report the incidents, which as such gives an interesting signal concerning the level and maturity of school safety management and safety culture. The reporting of incidents has been regarded as a standard procedure for improving safety already for a while, especially at industrial and transport sectors with long tradition of safety management systems [10, 11, 15].

While considering the generalization of the result we are well aware of the fact that the incidents in the analysis are those the teachers and principals happened to report. There had to be lots of near-miss cases that were never reported, giving another reflection of safety management and safety culture at schools while reporting less severe near-misses has been regarded as an essential aim in preventing the more severe incidents and accidents from happening [12], although this relation is not always straightforward [13]. Despite of this assumption the study is the first one that creates a categorization of the incidents at schools. It would be possible to even construct a questionnaire on the basis of the categorization to gather widely generalizable data.

The result presented here might help researchers, principals, teachers and administration in education consider physical hazards and risks and prevent accidents in school and in the school environment. It also raises the safety issues in outside school learning environments up for discussion. The understanding of incidents with different lower and upper categories might improve safety culture by modelling 'un-visible as visible' which was one of the strengths of the used tool Green Cross application itself.

The reported incidents and their analysis gave a many-sided picture of the need of the resilience and improved safety culture at school environment. Several incidents included characters of outer actors (risks caused by people outside school) and happenings outside the schoolyard or building for example during forest trips. The variability and large functional area of school circumstances challenges the procedures, work distribution, shared communication and situational awareness, found as important human factors behind the incidents [18].

The results open a new perspective to safety management at schools. To raise safety awareness and to be able to acknowledge incidents and near-miss cases before these indicate more severe accidents there is need to report those. Systematically reported and analyzed incidents and near-miss cases help to carry out preventive actions. As we can model incidents in the physical learning environment with the categorisation it might be possible to take students as active promoters of safety culture too. E.g. even young students could evaluate the schoolyard, jungle gym etc. and collect and report incidents. Students may be even better at this than staff. However, the safety management of the school organization has to be established to engage and motivate teachers to report more actively, and based on properly analyzed reports, to take corrective actions, to share lessons learnt and thus improve proactive safety management. Also, students and parents shall be committed to safety management, to share safety values. This would be along the National Core Curriculum for Basic Education 2014 in Finland that claims for better safety culture and safety education in schools.

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Upscaling Construction Education: The Role of Construction Site Experiential Learning

John Aliu(✉) and Clinton Aigbavboa

Sustainable Human Settlement and Construction Research Centre,
University of Johannesburg, Johannesburg, South Africa
ajseries77@gmail.com, caigbavboa@uj.ac.za

Abstract. In upscaling construction education for the future, the role of construction site experiential learning cannot be over-emphasised among students of higher education institutions (HEIs). For most students, it serves as the foremost introduction to the intricacies of the industry. Through a structured questionnaire survey, this paper identified the possible benefits of construction site experiential learning in fostering construction education. The sample for this study consisted of one hundred and twenty-six (126) respondents drawn from professionals in the Nigerian construction industry. The study revealed that developing practical knowledge about the industry, familiarizing students with their responsibilities in their profession and improving students' knowledge of industry expectations are among the benefits of site experiential learning. This study found that there is an increased need for students to be reinforced with relevant work activities, to enable them function effectively in the industry. This study recommends that HEIs are to continuously re-evaluate their existing curricula to incorporate relevant work experiences to better prepare students for the rigors of the construction industry.

Keywords: Construction site activities · Construction industry
Internships · Nigeria · Experiential learning · Work experience

1 Introduction

In preparing graduates for the future of the construction industry, the benefits of exposing them to construction site activities (experiential learning) cannot be over-emphasised. For most students, it serves as the first introduction to the rigors of industry and its operations, which may go a long way in defining their career success. It provides ample opportunity for students to garner valuable work experience, which is pivotal to their undergraduate education. Ultimately, students who possess work experience are highly rated by the construction industry (Lowden *et al.* 2011). According to Wilson (2012), the industry continually seeks graduates with work experience as they are often furnished with requisite skills and competencies as well as stand a better chance of handling industry positions in design and supervisory roles. It therefore serves as an avenue which provides students access to the reality of life in the industry as they acquire ideas and skills, not readily available during conventional lectures. With the ever-growing demand for graduates to be equipped with more than

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just an academic degree, possessing work experience is fundamental. This study is significant because students of today will be saddled with the responsibility of developing the built environment tomorrow, to improve the quality of life for any society. From the foregoing, the roles of construction site experiential learning bode well for the improvement of construction education and it is against this backdrop that this paper examines the benefits from a Nigerian perspective.

Several researchers have explained the concept of experiential learning and its role in providing holistic construction education. According to Taylor (1988), it can be defined as a well- structured and career-related work experience obtained by students as part of their academic study and acquired before graduation. This implies that it provides students with an opportunity of enhancing their thinking processes as they prepare for life after school. Callanan and Benzing (2004) asserts that it is an avenue for students to improve their learning process, which boosts their abilities to secure their dream employment. This resonates the view of Mihail (2006), who states that the process is key in developing in-depth academic knowledge among students. It is also a connecting bridge between higher education and the construction industry as students are exposed to work activities. Gault *et al.* (2010) opines that students can experience a first taste of industry employment activities when they undergo construction site activities. From the various definitions, it can be deduced that the integration and enhancement of work activities for students during undergraduate education can go a long way in providing valuable experience prior to graduation.

Table 1. Benefits of construction site experience

Benefits	Literature sources
Reinforces the knowledge learnt in the classroom	Wasonga and Murphy (2006), Sattler *et al.* (2011)
Increases students' marketability after graduation	Callanan and Benzing (2004), Lowden *et al.* (2011), Sattler *et al.* (2011), Ayarkwa *et al.* (2012)
Improves understanding of the industry needs and expectations	Omar *et al.* (2008)
Provides further understanding of a students' career weaknesses and strength	Wasonga and Murphy (2006), Sattler *et al.* (2011)
Furnishes students with generic skills and on-the-job knowledge	Ross and Elechi (2002), Gill and Lashine (2003), Yorke (2006), Mihail (2006)
Bridges lecture room learning with industry reality	Garavan and Murphy (2001), Lam and Ching (2007), Mihail (2006)
Increases their knowledge base ahead of their various careers	Sattler *et al.* (2011), Gault *et al.* (2010)
Increased personal and social industry efficacy	Mihail (2006)
Provide monetary compensations for students	Gault *et al.* (2000), Mihail (2006)

Source: Researcher's literature review

Furthermore, construction site experience helps in the application of theoretical knowledge garnered from classroom (Wasserman 2008), as well improving overall academic performance (Gault *et al.* 2000). Mihail (2006) and Gill and Lashine (2003) states that it improves the skill-set among students as well as bolster their abilities to solve problems. Apart from helping students fulfil their academic program requirements, it also boosts their employment activities as well as building stronger résumé (Divine *et al.* 2007, Omar *et al*. 2008). It helps in softening the shock of transitioning from the classroom experience to the harshness of the construction industry (Garavan and Murphy 2001). Likewise, it provides students with information regarding the expectations of the industry as well as their roles in the various sectors. Table 1 provides a summary of the various benefits of construction site experience to students ahead of fitting into the construction industry.

2 Research Methodology

This current study adopted a descriptive survey design, because it was effective in providing both quantitative and numeric description of the respondents. The target population were construction professionals in the Nigerian construction industry, namely engineers, architects, estate surveyors and valuers, builders, quantity surveyors, land surveyors, and town planners. The selection of these construction professionals was made because they were likely to have a considerable amount of knowledge in contributing to the objectives of this study. This study adopted the random sampling technique because it gave all the participants an equal chance to be selected for the study with the same criteria. Most times, this method is used when the target population presents the same characteristics, or the sampling size is too large to represent the entire population efficiently and each member of the entire population has an equal chance of being selected as a sampling respondent. Hence, a total of 126 respondents took part in this study. The main instrument of data collection was a structured questionnaire which was designed by the researcher following a review of extant literatures. The instrument was endorsed by handing it to experts in the construction industry before using it for the study. In addition, focused group discussions were held with key stakeholders in HEIs including construction lecturers/educators and curricula planners. Also, closed-ended questions was used for the purposes of this study. This is because close-ended questions provided participants with a multiple of options to choose from without allowing them to put their opinions in their own words. The main advantage of using close-ended questions is the simplicity for data collection and analysis, thus less time consuming.

2.1 Mean Item Score

To analyse data collected, this study adopted the mean item score (MIS). The mean ranking of each item was presented to provide a clearer picture of the agreement reached by the respondents.

3 Findings and Discussions

3.1 Background Information about Participants

Respondents were requested to indicate the degree of importance of each of the roles of construction site experiential learning based on a five point Likert scale (strongly disagree = 1, disagree = 2, neutral, = 3, agree = 4, strongly agree = 5). One hundred and twenty-six complete questionnaires were received signifying an 84% response rate. Findings from the 126 usable questionnaires revealed that a total of 98 males took part in the study which represents 77.8% of the total population. A total of 22 females took part in the study which represents a total of 22.2%

Also, 3.2% of the respondents were in the age group of 21–25 years old, 10.3% of the respondents were in the age group 26–30 years, 13.5% were in the age group 31–35 years, 17.5% were in the age group 36–40 years, 23.0% of the respondents were in the age group 41–45 years, 11.1% were in the age group of 46–50 years, 11.9% were in the age group of 51–55 years and 9.5% of the respondents were above 56 years old.

It revealed that 0.8% of the total respondents had less than a year's work experience and 4% had less than two years of work experience. It also revealed that 23.8% had experience that ranged from three to five years, 27% had experience in the range of six to ten years, 12.7% had experience that ranged from 11 to 15 years, 17.5% had experience that ranged from 16 to 20 years, 12.7% had experience that ranged from 21 to 25 years and 1.6% of the respondents had more than 25 years of industry experience. The years of experience of respondents were sufficient to provide useful responses to achieve the purpose of the study as 95.3% of the respondents for this study had over three years of work experience in the construction industry.

3.2 Mean Item Score for Ranking of Roles of Construction Site Experiential Learning

The mean ranking of each attribute was presented to provide a clearer picture of the agreement reached by the respondents. A summary of the test result is shown in the table below. The mean for each variable included the standard deviation.

Table 2 reveals the respondents' rankings of the possible benefits of construction site experiential learning in upscaling construction education. Respondents were requested to indicate the extent to which each of the following were benefits of construction site experiential learning using a five-point scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree. The table shows that, with a mean score (M) of 4.78 and standard deviation of (SD) = 0.504, 'developing practical knowledge about the industry' was ranked the most important role of construction site experiential learning. 'Familiarizing students with their responsibilities in their profession' was ranked second with (M = 4.52; SD = 0.603); 'improving students' knowledge of industry expectations' was ranked third with (M = 4.45; SD = 0.652) while 'applying theories learnt in the classroom', 'improving students' critical thinking abilities' and 'acquiring and developing various skills required by industry' were ranked fourth with (M = 4.44; SD = 0.573), (M = 4.44; SD = 0.587) and (M = 4.44; SD = 0.601) respectively.

Table 2. Result of mean item score

Roles of experiential learning	Mean	Standard deviation	Rank
Developing practical knowledge about the industry	4.78	0.504	1
Familiarizing students with their responsibilities	4.52	0.603	2
Improving students' knowledge of industry expectations	4.45	0.652	3
Applying theories learnt in the classroom	4.44	0.573	4
Improving students critical thinking abilities	4.44	0.587	4
Acquiring and developing various skills required by industry	4.44	0.601	4
Providing the necessary on-the-job training	4.43	0.650	5
Instilling the right kind of work attitude in students	4.41	0.673	6
Understanding the effective use of technology in the industry	4.40	0.718	7
Improving the resumés of graduates	4.39	0.657	8
Improving students' knowledge of industry challenges	4.39	0.692	8
Improving motivation level in students	4.35	0.773	9
Establishing rapport between students and professionals	4.34	0.609	10
Cultivating students' adaptability and creativity	4.34	0.671	10
Building networks with other interns on-site	4.34	0.739	10
Creating an industry mentorship forum for students	4.34	0.669	11
Exposing graduates to real life job experience	4.32	0.531	12
Providing opportunities to solve industry problems	4.31	0.665	12
Creating a better understanding of global issues	4.31	0.675	13
Exposing student to a range of career opportunities	4.30	0.597	14
Improving the knowledge of industry roles	4.30	0.661	14
Enhancing academic program relationships with industry partners	4.29	0.549	15

Source: Researcher's work

The table also shows 'providing the necessary on-the-job training' was ranked fifth with (M = 4.43; SD = 0.650); 'instilling the right kind of work attitude in students' was ranked sixth with (M = 4.41; SD = 0.673); 'understanding the effective use of technology in the industry' was ranked seventh with (M = 4.40; SD = 0.718); 'improving the resume of graduates' was ranked eight with (M = 4.39; SD = 0.657); 'improving motivation level in students' was ranked ninth with (M = 4.35; SD = 0.773); while 'establishing rapport between student and industry professionals', 'cultivating students' adaptability and creativity in the industry' and 'building networks with other interns on-site' were all ranked tenth with (M = 4.34; SD = 0.609); (M = 4.34; SD = 0.671) and (M = 4.34; SD = 0.739) respectively.

Moreover, the table further revealed that 'creating an industry mentorship forum for students' was ranked eleventh with (M = 4.33; SD = 0.669); 'exposing graduates to real life job experience' was ranked twelfth with (M = 4.32; SD = 0.531); 'providing opportunities for students to solve industry problems' was also ranked twelfth with (M = 4.32; SD = 0.665). Furthermore, the table revealed that 'creating a better understanding of global issues and social change' was ranked thirteenth with (M = 4.31; SD = 0.675); 'exposing students to a range of career opportunities upon graduation' was ranked fourteenth with (M = 4.30; SD = 0.597); 'improving the knowledge of the qualifications and duties for a specific position (role) in the industry' was also ranked fourteenth with (M = 4.30; SD = 0.661) and 'enhancing academic program relationships with industry partners' was ranked the least (M = 4.29; SD = 0.549).

4 Summary and Implication of Finding

Generally, there is a significant gap between lecture room experience and industry activities. As part of ways to bridge this gap, there is the need for students to be handed prior work experience which provides the required practical exposure and better understanding of their chosen profession. It can therefore be seen as a deliberate effort to develop actual work situations where real-life experiential learning can take place, so as to complement knowledge garnered during conventional lectures. Sometimes, these work experiences can be regarded as 'Supervised Work Experience' (SWE), 'Work Placement', 'Work-based Learning' and 'Work-Integrated Learning. These various terminologies help students to: acquire more skills in their field of study while obtaining their degree, enhance their holistic learning process, understand the various work ethics and demonstrate their abilities when the need arises. With the construction industry of today becoming increasingly dynamic, it is essential for students to possess a résumé that includes industry-exposure, as it hands them extra advantage. From this study, the significance of integrating real-world experiences into the HEIs educational curriculum has been identified as a vital component of students' development and hence, should be encouraged.

5 Lesson Learnt, Recommendations and Conclusion

The study set out to investigate the various roles of construction site experiential learning in fostering construction education. Various findings from literature describe it as key in giving students a better view of the various operations and intricacies of the industry. It affords students the first-hand opportunity of understanding what the construction industry entails. Its role in equipping students with academic and non-academic skills and competencies as well as improving their chances of job placement after graduation was also highlighted. In the achievement of career goals, work experience also helps students to be conversant with their strengths and weaknesses regarding their career choices and goals. The study recommends that HEIs are to improve construction education by also introducing courses that provides students with non-academic skills to fit into the industry. Likewise, the industry or construction sectors should ensure trainees benefit from all possible areas as possible. This can be done by ensuring students are rotated around various departments and ensuring supervisors are appointed to mentor them to ensure an all-inclusive learning process. It is also recommended that HEIs adopt measures to re-design work programs to align with educational curricula and teaching methods to enhance quality construction education for nation and beyond.

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Salman Nazir, Anna-Maria Teperi, and Aleksandra Polak-Sopińska

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In the original version of the book, the following belated corrections have been incorporated:

Author name "Wally Smith" should be included in chapter "Challenges in Creating a Mobile Digital Tutor for Clinical Communications Training".

Affiliation of editor "Aleksandra Polak-Sopinska" should be changed as "Department of Production Management and Logistics, Faculty of Management and Production Engineering" in Frontmatter and chapter "Challenges for Logistics Education in Industry 4.0".

The correction book has been updated with the changes.

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