INTERNATIONAL CONFERENCE ON **ENGINEERING AND PRODUCT DESIGN EDUCATION**
4 & 5 SEPTEMBER 2008, UNIVERSITAT POLITECNICA DE CATALUNYA, BARCELONA, SPAIN

DESIGN EDUCATION WITH SIMULATION GAMES

Tero JUUTI[1], **Poul Kyvsgaard HANSEN**[2] **and Timo LEHTONEN**[1]

[1] Tampere University of Technology
[2] Center for Industrial Production, Aalborg University

ABSTRACT
This paper is a brief report on the use of simulation games in design education. Our objective was to find solution to the question: "How to do design education effectively and efficiently for hundreds of people with minimum resources?" In the paper the learning theories are described in very short. Our focus is to describe observations and recommendations for people who have similar challenge. In the end we have discussion e.g. about the drawbacks of the learning method.
Two different simulation games were used; one with the university students and another with the industry people. At university quantitative data was gathered from exams and the results with and without simulation game were compared. Especially the learning of poorly motivated students was very impressive when using simulation game. The data from industry is based on observations while using simulation game. The results were that each of the workshop, game, and simulation elements can support the effort if configured and synchronized properly. The simulation games are valuable method for design education with skilful design and scoping.

Keywords: Simulation games, design education, concept mapping, learning circle

1 INTRODUCTION

The industry is seeking people who are capable of designing competitive products and services. The design task is more and more complex; the product must be innovative, competitive, it has to re-use platform components, it has to be modular and serve the needs of several stakeholders along it's lifecycle.
These demands are common for design educators. The competition and business environment imposes severe challenges on the teaching of new product development. At the same time there is less time and educators available. The design education is done also for people in industry and there the additional challenge is to create an environment they are able to conceive what is possible, how to do it and take decision when to do it. To summarize, there are more design phenomena to teach, more complex phenomena to teach and scarce resources available to deliver the learning solution.
These are the main drivers for us to test teaching with simulation games. In these simulations the participants are given a design task, some inputs and resources. The outcome is evaluated against pre-defined criteria and the results are used as input for next step. In our case, simulation is a tool to run sessions where people learn collaboratively with structured process, facilitation and guidance.

2 RELEVANT THEORY BASE

Simulation games are based on constructivistic learning school and problem based learning. We have used the zone of proximal development from Vygotsky[1] and Problem based learning described by Savery et al[2]. Our basic approach is to build on constructivist methods. The theory is that learner is able to learn by connecting new concepts to existing mental model the learner already has. The role of teacher is more of facilitation by guiding the learning processes. Key methods for facilitation are 1) modelling the key learning steps, 2) scaffolding - providing timely support for the learner and 3) to have learner to reflect upon learning challenge as described by Hmelo-Silver[3]. Key tool for learning is to give design tasks (*Concrete experience*), stop to consider what happened (*Observation and reflection*), modelling and discussion (*Forming abstract concepts*) and select the focus for next task (*Testing*). These steps are according to Kolb [4].

3 CREATING COMPLEX STRUCTURE WITH DISTRIBUTED TEAMS - UNIVERSITY CASE

The simulation game is developed by Tero Juuti, Timo Lehtonen and Pekka Leskelä. The target audience is students about to complete their studies who are attending Modularisation- course. The course consists of seven 2-hour lectures, the simulation game and examination. In the simulation game the key question is: “How to design a module system?” This question is decomposed into following sub-questions: 1) What design process steps are needed? 2) What design artefacts are created? 3) What are the dependencies between process steps and artefacts? We have identified enabling factors for the students to be successful in this endeavour. The enabling factors are information sharing and co-creation with creative tension, team roles and centralised control vs. self-organising. Although the focus is on design tasks the way how teams interact has a fundamental impact on success.

The set-up in the simulation is following; there are 10 teams each having 5-6 students. The students have different major subject therefore the teams are cross-functional by nature. The duration of the simulation is seven hours (breaks included). The briefing takes 45 minutes, the design tasks altogether 120 minutes, reflection, modelling and focus selection in total 180 minutes. There are two facilitators that guide the learning processes. The Lego-bricks are used for each design task and problem domain is space station. The overall objective for the students is to create such a modular space station that the final assembly takes less than ten minutes. The learning process is structured according to the “V-model” [5]. We bring in time constraints and skip the top-down approach totally because of lack of time. The top-down and bottom-up approaches are taught during lectures based on the design process of new modular product [6] There are seven simulation steps in the bottom-up process and the outcome of each team is verified against pre-determined criteria that is communicated to the teams.

The main tool is the workbook for each team and it is used in each simulation step. The workbook has the steps from the Kolb´s learning circle with some scaling questions included. In the reflection part the team make self-assessment on three issues; 1) what went well, 2) how to improve and 3) what is the new challenge or key question. This material is used for the modelling and quite often the team finds new concepts and focuses for the next step. These ideas are the used to agree the focus areas within the team for the next design task. The workbook is presented in figure 1.

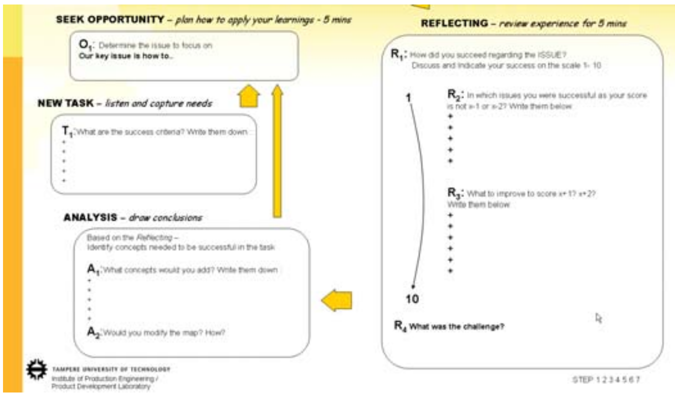

Figure 1 The workbook with learning circle adapted from Kolb.

The scaling question is used in Reflecting-section to have successful items and improvement ideas during the reflecting. The scaling question forces student to really analyse in which aspects they were successful and which aspects were neglected intentionally. If the aspects were neglected by accident and student is able to identify this then learning has clearly taken place. The students use concept mapping for reflection and concept forming to facilitate learning. The concept mapping is developed by Joseph D. Novak [7] and it is based on the cognitive theories of David Ausubel (assimilation theory), who stressed the importance of prior knowledge in being able to learn new concepts. Figure 2 is an example of refined concept map after the team had converted it into electronic format.

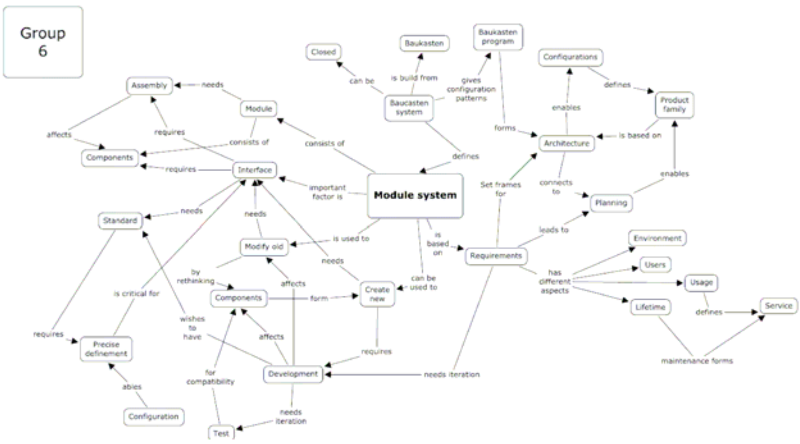

Figure 2 Example of ready-made concept map. The aim of the map is to provide answer to the question "How to design a module system?"

The modelling was done with CMAP-tool [8]. The concept maps served well as several rounds of learning circle was used. Each team refined and updated their concept map during every round and the concept map was used to identify which concept each team member will focus during next concrete experience-phase.

The analysis is done with the data from examination answers. The exam had five questions; one from the simulation, two easier and two advanced questions from the lectures. There were 65 participants in the exam and our results show clearly that topic taught with simulation was learned much better that topics with normal lectures. The results were normalised because 7-hour simulation is much longer than 2-hour lecture. The finding is that simulation improves learning results and the effectiveness of the learning is superior. The use of simulation game enables that topics with intermediate difficulty can be taught with same effort than basic topics with good learning results. Another finding was that learning was more efficient among the students who had lowest grades when comparing to those who has got the highest grades. This implies that simulation is very beneficial to those who have low motivation or learning disabilities.

4 PLATFORM SIMULATION – INDUSTRY CASE

Platform is a concept that involves various theoretical perspectives (i.e. organization, innovation, supply chain management, economics, etc.). Although the philosophy behind platforms and platform thinking is easy to communicate and makes intuitive sense, its implementation can be extremely challenging due to the inbuilt complexity.

One particular problem is to foresee qualitative and quantitative effects of the platform effort. Since platform initiatives affect cross-organizational units and financial periods, the challenges related to organizing and communicating these initiatives become highly complex.

To make students learn we need to introduce interactive methods that support experimentation and reflection [4]. In educational settings learning can be supported by the use of specific case environments. We don't use environment in the ecological sense but in the sense of the sum of all forces that affect an organizations actions. When we learn we get a better understanding of this environment, we can improve our ability to adapt to the environment, or we can change the environment. It is our experience that the means in the learning process can be conceptualised into three categories: Workshops, Simulations, and Games.

The three means have different characteristics that when applied in the specific environment stimulates the various elements of the learning process. We have developed and tested a specific platform decision learning set-up that takes outset in a specific LEGO product program. During workshop activities the different available methods have been discussed as have the strength and weaknesses of the available information. In cases where the information has been detailed a number of simulations have been conducted. In parallel a game reflection the whole supply chain have been played in a cardboard version.

The initial test on the workshop, simulation, game set-up has been limited to three products in one particular product line. Among our initial observations are:

1. The number of variables is too big to overviewed and handled by a workshop.
2. There is a high risk of the solution being either a compromise (that we really don't know the consequences of) or a solution based on what we have done before (that we really don't know the consequences of either).
3. The complexity is too high to be handled by simulations. The effort to build a comprehensive model that can cover the complexity is huge and the risk of not succeeding is high. However, critical elements can be simulated and detailed parts of the solution or refinements can be supported by simulations.

4. Games can only give superficial indications of a solution. However, they can support in testing the robustness of a chosen solution.

The conclusion is that each of the workshop, game, and simulation elements can support the effort if the focus is narrow enough, the set-up is properly configured and synchronized.

5 CONCLUSIONS

The results indicate that including practical design tasks to the education enables less-motivated students to learn more effectively. The task needs to be a real challenge; worthwhile, interesting, attainable and in the zone of proximal development [1] – to have the motivation in place.

With simulation game we are able to demonstrate the need for successful information sharing in the team. The winning teams have also the ability to remain in the area of creative tension; balancing between group thinking and diversity with high quality of co-creation. The simulation game is able to increase awareness and understanding of these phenomena between people and thus cultivates persons behaviour to became a valuable asset for the company.

The use of practical design task and learning circle enabling reflecting improves learning. The scale question helps students to evaluate themselves how successful they were and how to improve the design solution next time. The use of concept mapping is a valuable tool for educators as it provides full access to students thinking and mental models.

With simulation it is possible to understand critical elements of the model and it is a method for further improving the model. Games can be used especially for testing the robustness of a chosen model or solution. One key element in learning is the negotiation about what concepts are needed, which meaning they carry and how identified new concepts relate to the existing ones. Enabling this dialogue among participants design educator ensures that everybody has the opportunity to learn.

6 DISCUSSION

One challenge is how to design well functioning simulations. The scoping, amount of learning topics, variety of activities and time management plays important role in this. Another challenge emerged while running the simulation in the university. There was deviation between the concept maps created by different teams. This is a challenge if the objective is to have identical maps from different teams. The differences occur due to different focuses of each team.

The focus dilemma was identified during observation as the educators observed students. The students were from different faculties and for example the students with industrial economic studies had focus on different items when comparing with students from machine design department.

The industry case demonstrates that the scoping of the simulation game is a key issue and requires expertise. If the phenomena, topic or challenge is too big the participants in the simulation session are not able to grasp the overall view. The sequence of the simulation game plays an important role, too. While designing the simulation one needs to pay attention how many phases, the duration and what kind of activity each phase requires.

REFERENCES

[1] Vygotsky, L. S. *Mind in society: the development of higher psychological processes.* (Harvard University Press, Cambridge 1978).

[2] Savery J.R., Duffy T.M., Problem Based Learning: An instructional model and its constructivist framework. *CRLT Technical Report,* 2001, 16-01

[3] Hmelo-Silver, C.E., Duncan, R.G. and Chinn, C.A. Scaffolding and Achievement in Problem-Based and Inquiry Learning. *Educational Psychologist*, 2007, 42(2), 99–107.

[4] Kolb, D. A. *Experiential Learning*. (Prentice Hall. Englewood Cliffs, NJ 1984)

[5] Stevens, R., Brook P., Jackson K., Arnold S., *Systems engineering – Coping with Complexity.* (Prentice Hall. Harlow 1998)

[6] Lehtonen T. *Designing Modular Product Architecture in the New Product Development.* (2007, Dissertation, Tampere University of Technology) p.169-173. http://webhotel.tut.fi/library/tutdiss/show.php?id=155

[7] Novak, J.D. and Canas, A.J. The Theory Underlying Concept Maps and How to Construct and Use Them. Florida Institute for Human and Machine Cognition. http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm

[8] Novak, J.D. and Canas, A.J. Building on New Constructivist Ideas and the CMapTools to Create New Model for Education. (First International Conference on Concept Mapping: Theory, Methodology, Technology. Pamplona, Spain2004). http://cmap.ihmc.us/

[1]Tero JUUTI
Tampere University of Technology
Hermiankatu 12, 33720 Tampere
tero.s.juuti@nokia.com
+358 50 3729054

[2] Poul Kyvsgaard HANSEN
Center for Industrial Production, Aalborg University
Fibigerstraede 16, DK 9220 Aalborg Oest, Denmark
kyvs@production.aau.dk
+45 40288935