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Design education with simulation games

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Abstract
This paper is a 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 short. Our focus is to describe observations and recommendations for people who have similar challenge. In the end we have discussion about the drawbacks of the learning method.

Two different simulation games were used; one with university students and another with industrial people. At university quantitative data was gathered from exams and the results were analysed. Especially the learning of low grade exam students was 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 skillful design, scoping and facilitation.
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Keywords: Simulation games, design education, university, industry.

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 concieve 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) modeling the key learning steps, 2) scaffolding - providing timely support for the learner and 3) to have learner to reflect upon learning challenge Hmelo-Silver[3]. Key tool for learning is to give design tasks (*Concrete experience*), stop to consider what happened (*Observation and reflection*), modeling 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

3.1 Introduction

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 key question is: **how to design a module-system?** This question is broke down 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 inter-operate has a fundamental impact on success.

The set-up in the simulation is as follows; there are 10 teams each having 5-6 students. The students have different major subject so the teams are crossfunctional. The duration including breaks is seven hours, the briefing takes 45 minutes, the design tasks althogether 120 minutes, reflection, modeling and focus selection in total 180 minutes.

There are two facilitators that guide the learning processes. We are using Lego-bricks for each design task and problem domain is space station. So, the overall objective for the students is to create modular space station and the main criteria is that the final assembly must take less than ten minutes.

The learning process is structured according to the “V-model” commonly used in systems engineering for complex systems [5]. In this case we bring in real life 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 steps in the bottom-up process and the outcome of each team is verified against pre-determined criteria that are communicated to the teams.

The main tool is workbook for each team and per each simulation step. The workbook has the steps from the Kolb learning circle with some scaling questions. 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.

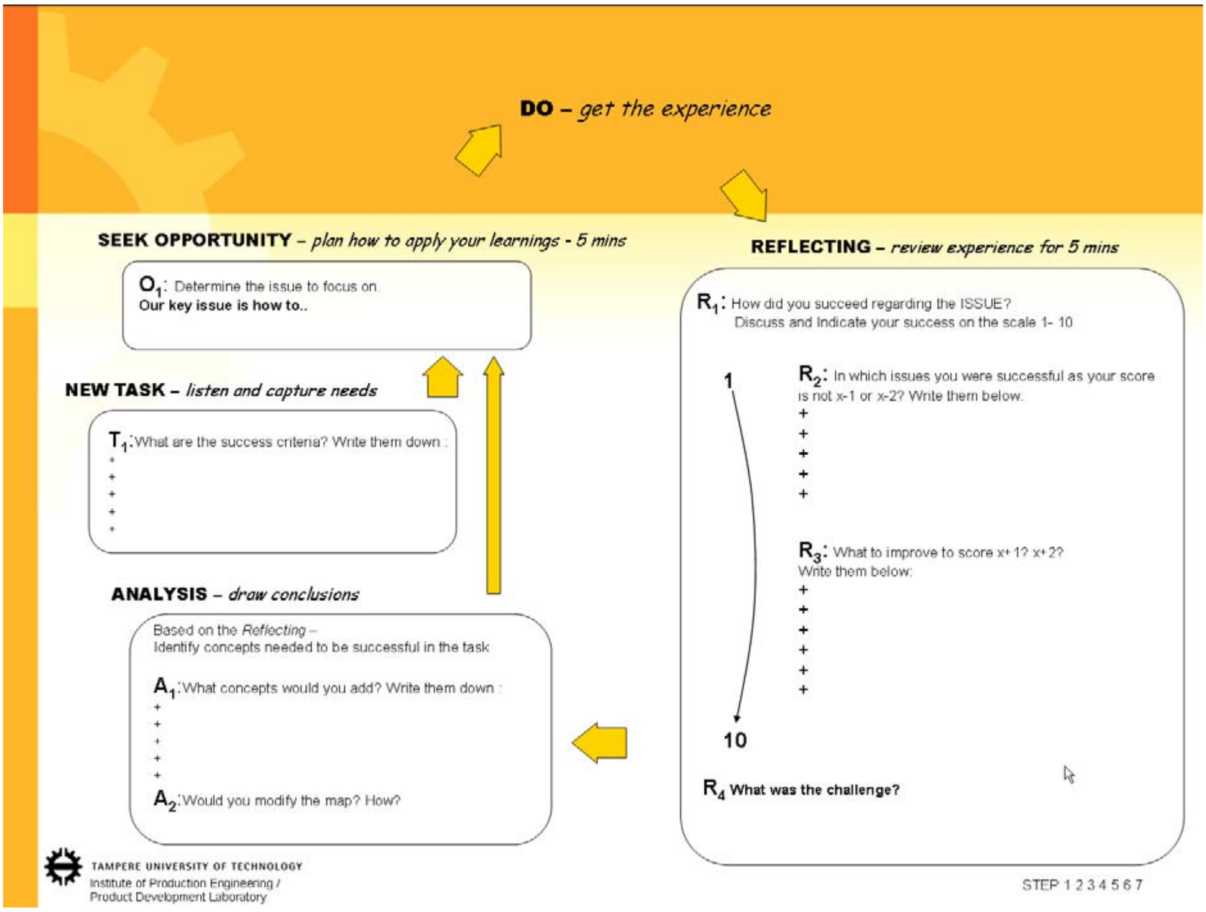


Figure 1 The learning circle adapted from Kolb.

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 used concept mapping for reflection and concept forming to facilitate learning. The concept mapping is developed by Joseph D. Novak [7] and it is 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 in electronic format.

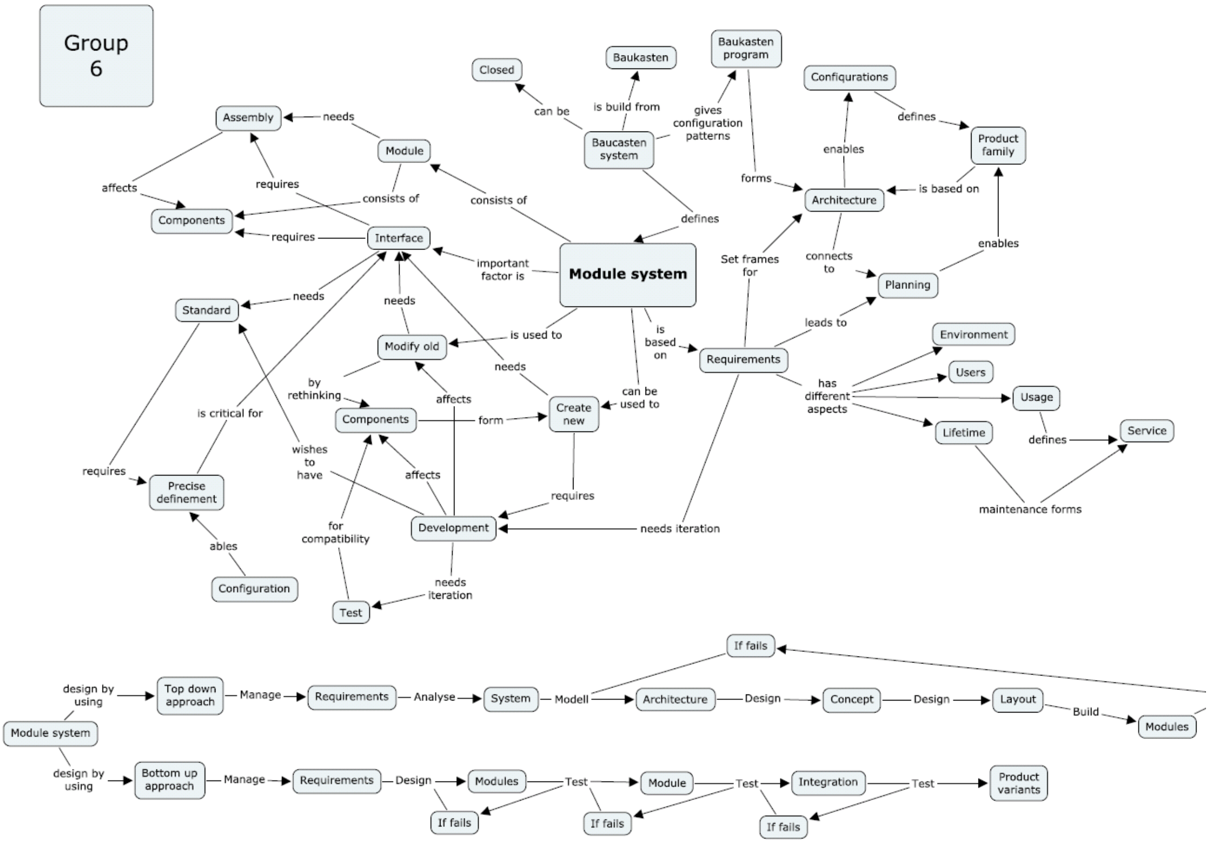


Figure 2 Example of ready-made concept map. The aim of the map is to provide answer to the question "How to design a module system?"

The modeling 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. One team refining concept map is in figure 3.

Figure 3 One team refining concept map based on the learning of one simulation step.

3.2 Results

Students can learn many things with simulation game (for example communication and team work). After all lectures and simulation was held the learning was assessed with exam. The exam had five questions, one questions was about the issues taught with simulation game and the other four about issues taught with lectures. Two lecture-based questions were easy, basic-level and two were more difficult, intermediate and advanced questions. There were 65 participants in the first exam. The number of correct answers are in the figure 4.

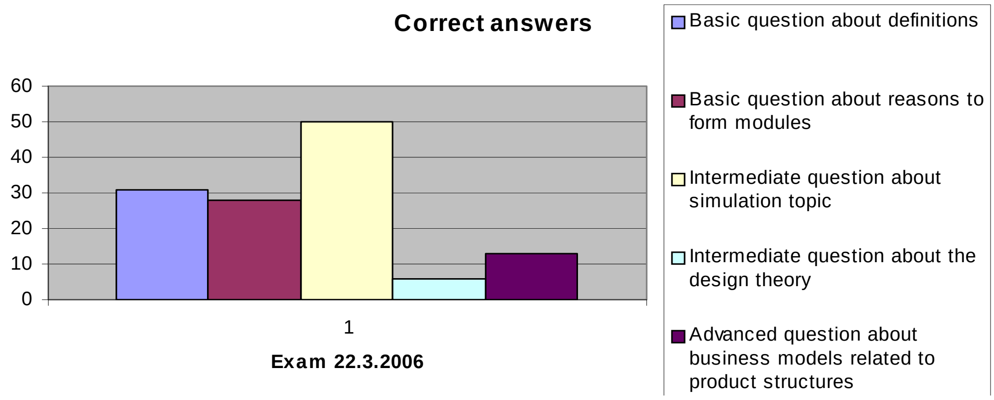


Figure 4 Number of correct answers in different exam questions.

Our results show that topic that was taught with simulation was learned better that topics taught with lectures. The 7-hour simulation cannot be compared directly to the 2-hour lecture, so the results are normalized. Here is summary of the hours used per exam question: question 1; 4 hours, question 2; 6 hours, simulation question 3; 7 hours, question 4; 2 hours, question 5: 4 hours. The number of correct answers is divided by how many lecture hours has been used for the learning topic. The results are in the Figure 5.

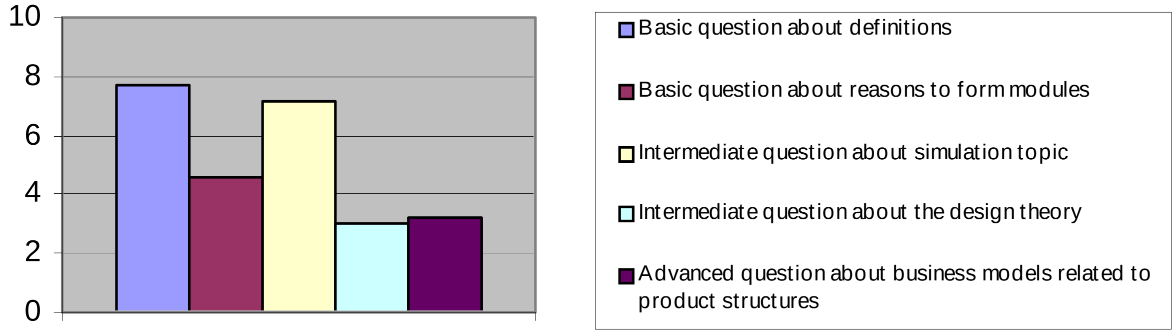
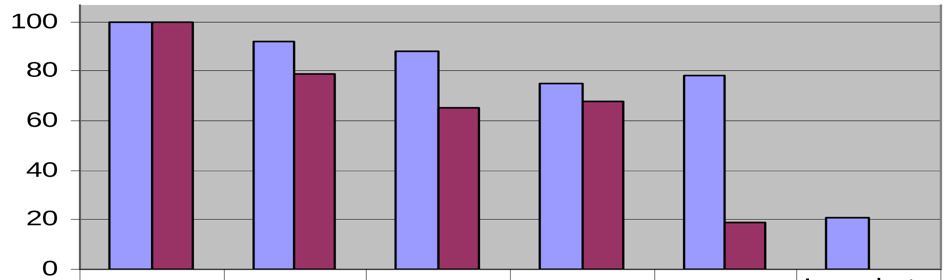


Figure 5. The amount of correct answers to five different exam questions after normalization.

The result is that students got remarkably more correct answer to question 3 comparing to easier question 2. The result of question 3 is more than 200% better comparing to question 4, which was on similar, intermediate level of learning challenge. With these findings, there is no doubt that simulation greatly improves learning. Even taking account the extra effort needed in simulation, the effectiveness of the teaching is still superior. When this is the case, topics with intermediate difficulty could be taught with same effort than basic topics.

We performed another analysis, too. We analysed how many students with different overall exam score were able to have correct answer to the question 1 and 3. The figure 6. shows the percentage of correct answer to both questions.



	5	4	3	2	1	Improbatur
Question3	100	92	88	75	78	21
Question1	100	79	65	68	19	0

Figure 6 Correct answer percentage to the questions 1 and 3 by the overall grade. The bar indicates how many students, e.g. with grade 1 answered correctly to question 1 and 3 (19% and 78%).

The result shows that learning has became more efficient among the students who had lowest grades comparing to those who got the highest grades. The conclusion is that people who have low motivation or difficulties in learning by lecturing benefit from problem-based, participatory method.

4 Platform simulation – Industry case

4.1 Introduction

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 inhered complexity.

One particular problem is to foresee qualitative and quantitative effects of the platform effort. Initially, some companies accept qualitative arguments so the platform effort can be started. However, as the company gain experience, requirements for both qualitative and quantitative methods become necessary. 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 conceptualized 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 setup 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.

4.2 Results

The initial test on the workshop, simulation, game setup 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 configured and synchronized properly.

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] – otherwise it is just artificial problem with no resonance with the student.

With simulation game it is possible 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 groupthinking 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 person's behaviour to valuable asset.

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 very 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. With this regard concept mapping was found to be very useful tool for teachers because students thinking is made visible and the continous learning easy to follow and facilitate

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 part for successful simulation. The university simulation enables learning up to sixty persons per session with two facilitators. It involves people and everybody creates conceptual model and mindset on the topic. This seems to facilitate learning especially for people with poor learning abilities or low motivation. This case indicates that simulation is efficient and effective learning method and that the simulation design was successful.

One challenge became evident while running the simulation at the university. There was deviation between the concept maps created by different teams. This is a challenge if the objective is to get similar maps from different teams. The educators observed that background knowledge and abilities varied a lot among the students. The students were from different faculties and students with industrial economic studies had focus on different items when comparing with students from machine design department. During the simulation different teams had different focuses probably because of the different approaches and focuses of different faculties. This is one potential explanation to the differences of the concept maps.

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 participants in the simulation session are not able to grasp the whole. The sequence of the simulation game plays an important role, too. While designing the simulation one needs to pay attention how many phases, how long phases and what kind of activity each phase requires.

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