Serious Games in Engineering Higher Education

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Abstract

The traditional education of engineers is dominated by technical issues and partly business knowledge. Management skills are required but rarely trained. On the one hand, there are many theories about leadership abilities, teamwork, decision-making processes and intercultural co-operation, and theoretical lectures are a common way to teach these theories and skills. But the results are not satisfying. Regarding to the university education this leads to the requirement to teach beside technical and methodological abilities as well social competencies. But on the other hand, there are very few ideas of teaching these abilities. However, the industry reflects an inability of the students to carry out management skills. Therefore, the author offers management courses within the engineering higher education, which are exceptional in that offering the training of management skills by the application of three different serious games. The first type of game deals with leadership abilities and teamwork. The second game is a business game training decision-making processes and consider downstream consequences. The firstly trained skills should also be applied during this second game. The third game deals with intercultural co-operation. They have to apply their already trained management skills as well. The management courses are compulsory and they are offered in bachelor and master degree courses for mechanical and civil engineers. The following paper offers an overview on these games and a comparison of the different tasks within the games related to the trained skills.

Keywords

higher education; engineering; social competencies; serious games; soft skills; inter- and transdisciplinary

Introduction

Engineers are the leading forces of economy, they drive innovation and development. They need to get a well based engineering education, which is described by technical, technological and engineering abilities including methodological and economic knowledge. But, engineers need management skills as well. This means that beside the typical engineering education social skills have to be taught, too. Social competence is used in the sense of "ability and willingness of group and relation oriented actions and behavior within a working process" concerning to /Neef 2008/. Through surveys, interviews, and questionnaires it turned out that alumni show a lower social competence than expected by employers. This requires an intensive discussion and evaluation about the possibilities to teach social competencies.

To train social competencies this term has to be defined in the sense industry requires social skills. This assures to gather the different skills on the one hand and on the other hand it offers the possibility to develop a special training for the identified skills. Within a survey first skills have been gathered. The results of the survey are not published, these university internal data. Based on this data additional expert interviews have been carried out to identify the skills exactly and to identify as well the situations which lead to missing skills. These results are out of the employers' perspective. The following paper is based on this data by matching social competencies to fields of success. The fields of success are matched to different serious games training the required skills /Hoeborn, G. 2016/.

Managers have to make decisions within short time. Universities get the task to train and to enable students to accomplish with the changing and dynamic requirements of the employment market. Therefore, they have to train the success factors within their studies. The growing complexity and dynamic of tasks lead to a higher awareness and ability of co-operation, communication, and social competencies /Probst, Büttel 1994/. Employers need to know and be enabled to decide and to define how to act within or to relations of other involved participants /Swart, Wild 2001/. Regarding to higher education this leads to the requirement to enable the students to use their competencies in the situations they are needed. To reach this success the person needs, on the one hand, the ability to communicate and co-operate and, on the other hand, the ability to perceive and recognize in how far the performance of all involved partners influences the co-operation, included the self-performance. Employees have to be enabled to adopt their performance situationally.

Higher education has to offer technical, methodological and social competencies. Concerning the teaching of technical, technological, and methodological abilities there exists a broad offer of possibilities to teach like lecture or exercises up to project work. Regarding to the training of social skills the portfolio is bounded. The application of serious games is one possibility to train social skills. The application of games within education is defined as Serious Games / Wouters, P., van der Spek, ED.; van Oostendorp, H. 2011/ and they are hypothesized to address the cognitive and affective dimensions of learning / O'Neil, H.F., Wainess, R., & Baker, E.L. 2005/. Serious games offer many advantages to the author's opinion, but they are not applied very often in higher education. Serious games include entertaining goals as well as educational objectives, and they are, therefore, an innovative teaching methodology. Results regarding the application of serious games in engineering education show the improvement of students' abilities concerning management skills. Serious games have a long tradition regarding military and economic offers, the application for civil purposes is increasing more and more from business games up to logistics. The common condition required for all serious games is the individual activity of the students by applying. Serious games are characterized by a directly related and specific experience as well as by a reflexion and assessment process following the application, the gaming. Thereby, the students experience and reflect the consequences of their activities and decisions leading to a new way

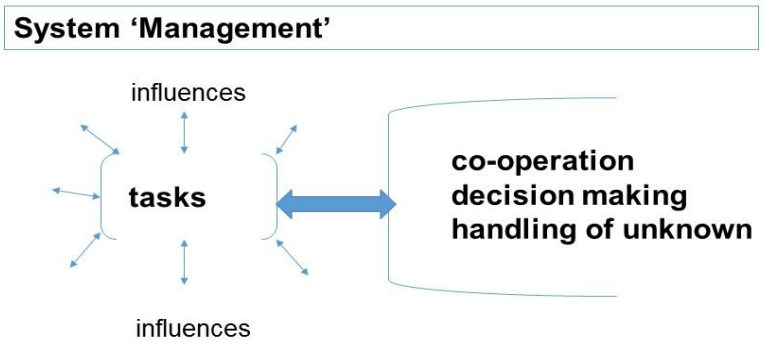
of awareness and, at the same time, improving their abilities. Additionally, one of the advantages of serious games is to learn individually in a holistic context. Serious games are applied for life-long-learning purposes as well / Baalsrud Hauge, J. et al. 2009/. Through gaming, the students increase their competences lifelong depending on the game subject related or social skills; they improve individually / Pikkola, H. 2004/.

The following paper presents three different serious games by matching the game to the skills to the success factors. These three games are used within higher education, within engineering education at the University of Wuppertal.

Content of teaching

Within the engineering education beside technical, technological, and methodological abilities social competencies have to be taught. Social competencies include all the abilities a manager needs to fulfil his/her tasks, therefore, they are also called management skills. Engineering curricula include management methodologies without defining the management success factors. Additionally, it is difficult to draw a strict border between methodological and social skills due to their connections.

Figure 1: Management System



The different interviews and surveys carried out like being described in the introduction underlined three great fields of success factors which have to be trained: co-operation, decision making, and handling of unfamiliar. Looking at the system 'management' the limitations are given through *defined goals*, meaning tasks that have to be fulfilled, *strong expectations*, like sticking to a time schedule, *different personalities* of the actors. These parameters are permanently influencing the system. So, the systems is characterized by different influences, in the sense of expectations, acting as input at the system. Within this boarders and expectations there are the three complex success factors co-operation, decision making, and handling of unknown. The tasks and goals within the system management can only be solved and fulfilled if all three success factor fields are available. These success factor fields themselves include many success factors, various abilities. The following success factors have been developed on the basis of the expert interviews and surveys.

The success factor field of *co-operation* includes:

- Success factor *leadership*, including the leading of a team with the regarded tasks and responsibilities like power to direct, power to decide, being in charge of results, social responsibility regarding team, conflict management e.g.
- Success factor *ability to work in a team*, teamwork as a way to co-operate by being equally entitled. This requires tolerance, acceptance, openness, reliability, and confidence.
- Success factor *distribution and acceptance of roles*, the team members have to be aware of the existence of different roles which have to be distributed, accepted and fulfilled, this includes leading the team as well.
- Success factor *self- and time-management*, these issues are related to methodological skills as well as to social skills. They deal with giving priorities regarding the time schedule.
- Success factor *estimation of potentials, perception and acceptance of limitations*, regarding management processes existing potentials have to be estimated and evaluated within a short time, this requires the perception and acceptance of limitations.
- Success factor *handling of competitive situations*, the team have to consider that they are within a competitive situation but it has, at the same time, to be able to focus on its own goals.

Additionally, the success factor field *decision making* includes –beside the already mentioned success factors of co-operation:

- Success factor *balance of alternatives* by taking consequences into consideration.
- Success factor *evaluation of information,* conceiving of the main information by having time and competitive pressure.
- Success factor *risk management*, decision making by being aware that unpredictable influences could lead to negative results, estimation of risk concerning reliability and seriousness.
- Success factor *networking*, awareness of influence of networking.

Additionally, the success factor field of *handling of unknown*, includes –beside the already mentioned success factors of co-operation and decision making:

- Success factor of *compulsory co-operation* even when unexpected difficulties appear like situations with seemingly insuperable difficulties through different priorities by disciplines but having a mandatory co-operation.
- Success factor *intercultural competence*, nowadays the working environment is characterized by global networking and a global working market. Within an enterprise different cultures having different values are working together, tolerating and accepting each other.

The described success factor are intensified by communication, self-reflection, and continuous improvement issues.

Teaching Methodology

Competencies are taught in general through lectures, seminars e.g. Knowledge and experience are taught, learning experiences are missing. Learning experiences aim on the perception of the own and the other's knowledge as well as they aim on the ability and qualification to understand the opinions and attitudes after this process of perceptions and to use them adequately /Illeris, K. 2010, Metz, M. and Theis, F. 2011/. This kind of a learning experience leads to flexibility and the sense of responsibility, the ability of problem solution, system thinking and the ability of co-operation. The students learn playfully specific abilities

through learning experiences caused by serious games, mutually with other students by having restricting rules. There may be a competitive gaming situation, but at the same time there is always joy, excitement and active communication. This combination out of gaming and learning aim on training especially abilities of social and methodological competencies. The learning goals are not always obvious, they are sometimes implemented in the game. By choosing specific serious games an increase of improvement of the trained success factors can be reached.

Serious games are defined as follows regarding to the definition of Clark C. Abt

'*Reduced to its formal essence, a game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context. A more conventional definition would say that a game is a context with rules among adversaries trying to win objectives. We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.' (*Abt, C. 1970)

Nowadays serious games cover a broad field and they are still not defined uniquely. Their application is undoubted from primary up to tertiary education, it supports the intellectual capital as well as the know-how. Serious games are characterized by an active gathering of competencies.

Situation in class and Serious Games

Three very different types of serious games are carried out within classes for civil, mechanical, and safety and security engineering. The three games offer a very different content, and, depending on this, the students have to develop innovative and sustainable solutions, make decisions having downstream consequences, or find compromises to negotiate. Serious games appear very differently, the three games described in this article are non-digital games.

They are applied as already mentioned in engineering lectures using a mixed learning concept. The classes include a couple of separate lectures. It starts with introduction lectures, where different management systems, teamwork, communication, cultural influences and various decision-making theories are taught and discussed. It is very important to create an atmosphere of trust and confidence during these first lectures. The students have to feel comfortable and to be confiding when gaming later on. The following lectures are used for gaming and reflections. If necessary the distribution of roles and groups is organized. Within the process of teaching the improvement of the students is evaluated by estimating their learning successes out of the previous games.

This paper deals with the following three games: Lego Racers Championship developed by a consultancy for Lego (effective 2011), **E**ntscheidungsfindung **f**ür **e**ine **U**nternehmensstrategie (EfeU) developed by Jennifer Bredtmann (2008) and further developed by Gabriele Hoeborn (2012), and the third one is the TeCuVa (**Te**amwork within different **Cu**ltures and **Va**lues) which is like the Cocktail Party Simulation by Daphne A. Jameson (2007) just modified to engineering purposes. These three games improve and support the management skills of the students actively, especially regarding to the success factors leadership, decision making, teamwork, networking, gender sensitive, and intercultural competence within a dynamically changing working environment.

Lego Racer Championship

Success factors: Leadership, Teamwork, role distribution and acceptance, estimation of potential, dealing with time and competition pressure, self- and time-management

Additionally: Communication, Continuous Improvement

The number of groups playing the Lego Racers Championship is not limited. It is a competitive game having the obvious goal to score as many points as possible. When starting the LEGO game pedagogical issues are not discussed. The students get all the information about the game via power point as listed. All necessary stuff is offered to them. The students may communicate within their groups during the whole game. Usually about 10 students are within one group. The belonging to a group may be random or driven by lecturer, it is depending on the group and its group dynamic. The lecturer choses the team leader of each group. Originally there had been a detailed description of game by an internet link, but it does not work a ctually. The game originally purposed on being applied within enterprises on management levels. Some modification were carried out to simplify the application for the students. In general, the students have to build cars out of Lego bricks, no motors are available. These cars participate in a racing within a race track of about 3 m having a bull's eye at its end and a Launch Area at the starting point. The goal is to score as many points as possible. The students get two phases to act to. The first phase is the preparation phase in which they can build and test the cars. Additionally, they get scissors, card board, adhesive tape and the boxes with the Lego bricks. They may build any kind of a construction within the launch area which may be changed during the entire game by using the given materials. The second phase is the racing phase in which the cars have to be started from the launch area and should score at the bull's eye. The given time limit 20 minutes includes both phases. Just during the racing phase points are scored. At the same time, the group may lose points by touching a car in motion, destroying a car, or by not reaching the bull's eye. Additionally, advices are offered which the students may buy. These advices are very cheap during the preparation phase. The students do not know which kind of an advice they will get when buying one. After gaming there is a feedback lecture, evaluating the students' decisions and performance. These parts combines cognitive and constructive learning paradigm by including problem based and experimental learning. Very important is the active participation of students in the process of gaming. At the end of this evaluation the students are told which team won the game.

EfeU

Success factors already trained with the Lego game: Leadership, Teamwork, role distribution and acceptance, estimation of potential, dealing with time and competition pressure, self- and time-management

Additional success factors: evaluation of alternatives and estimation of consequences, evaluation of information, risk management and awareness of imponderability, networking and synergy effects

Additionally: Communication, Continuous Improvement

EfeU is a business game which was developed by Bredtmann (2008) especially for the use in higher education and it was developed further on and adopted by Hoeborn (2012) to the engineering degree courses. It focuses on the simulation of complex processes in and between companies. The field of application is a bike company. Within this management game decision making and co-operation processes are trained. The awareness and knowledge about decision making and the handling of a group including performance within the group are the central elements of this game. The dealing with information and knowledge and their transfer

and implementation are trained as well. EfeU simulates the different company processes by simplifying them at the same time. Related decisions have to be taken and downstream consequences have to be considered. The economic profit seems to have priority, pedagogically it focusses on raising awareness and experience processes of decision making and its consequences. Getting the highest profit is not the most important goal of the game. At a second level of evaluation, which is discussed after finishing the game, special decision making points can be gathered. The implicit learning goal is not explained to the students explicitly. But they know that their decisions are having consequences for the economic well doing of their company. The success of a gaming group is not just characterized by the profit itself as already mentioned, but at the same time by perception of the consequences of decisions as well as by the impact of team work within a decision process. So, several winner may appear. The game is aiming on training the interaction between decisions and consequences.

The students play in groups, the number of groups is not limited. Each groups enclose 5 – 10 students. If possible each group gets a separate room for gaming to discuss undisturbedly. The students are leading a company producing and selling bicycles. They get the task of steering all processes and requirements regarding to the company and the product by skillful decision making. All companies (equal to all student groups) have the same sales market, so the students are within a competitive situation. In general, the game is divided into two big phases, and each phase symbolizes a business year. For the first part of the game, part A, all student groups get their specific information regarding to their company like company key figures, sales figures, and capital. Additionally, they are offered information by letters with special offers by suppliers, product offers, investment possibilities, and costumer information. By evaluating the given data the students plan their business year. They have a time limit of about 30 minutes. After this time they can attend a so called 'forum' where they can invite and meet representatives of the other companies. They are free in their way to use this forum. It is a place to network, to co-operate, to change information. But there is no explicit explanation to do so. After this forum the students have to make up their decisions for the first business year. At this point the first phase of the game is finished. At the next term the students get their results within their groups concerning profit of the first term. Additionally they get new information. Partly this information lead to consequences of the decisions of the first phase. Again they have their part of discussing, meeting the forum, and finally making up their decisions. This is the end of business year 2 and the end of gaming. After the final ending of the game a feedback and a discussion is carried out. Within this evaluation the students identify their problems and the main experiences and decisions regarding to communication, risk management, and decision making including evaluation of alternatives and estimation of consequences as well as evaluation of information within time and competition pressure. The profit results of the students' group were offered, but at the same time the information which had to be considered for decision making are analyzed. The handling of the information and their downstream consequences are marked by decision points which influence the results of the groups.

TeCuMa (Teamwork within different **Cu**ltures and **Va**lues **– Cocktail Party Simulation)**

Success factors already trained with the Lego and EfeU game: Leadership, Teamwork, role distribution and acceptance, estimation of potential, dealing with time and competition pressure, self- and time-management, evaluation of alternatives and estimation of consequences, evaluation of information, risk management and awareness of imponderability, networking and synergy effects

Additional success factors: mandatory co-operation, unexpected difficulties, intercultural competence

Additionally: Communication, Continuous Improvement

Daphne A. Jameson developed the serious game 'cocktail party simulation' for training the ability of intercultural communication for hospitality managers. It was originally designed by her at the School of Hotel Administration of Cornell University, USA, and can be down loaded as tool no. 7, July 2007. Jameson offers this excellent game to train intercultural communication and the author stick to it just adapting German language and costumes. Hoeborn developed it further on in 2012 and adopted it to engineering education. Regarding to engineering education it is a valuable game to train intercultural competence, because it deals with handling of different cultures. Therefore, it trains the intercultural competence as well as it lowers barriers regarding to culture. At the same the game offers a specific task to fulfill, which may not be neglected. According to Hoeborn (2014) 'The author developed and coped this management and role-play-game especially for university education in engineering degree courses at bachelor and master level. Therefore, TeCuVa is a role-play-game and a business game at the same time. It offers the experience and training of decision-making and co-operation, of compromising processes within groups of quite different cultural background and values. The game supports the reduction of cultural barriers by creating an intercultural simulation, taking place at an engineering kick-off meeting. According to Jameson the game is aiming on four educational goals. Due to the situation of the cocktail party, the game demonstrates the principles and limits of intercultural communication realistically, firstly, by underlining and pointing out the relativity of cultural values and emotions related to these values and attitudes. The students experience these contradictions especially between the required professional performance and emotional stress. The second educational goal is to live the obvious and visible cultural manners as well as the invisible cultural values themselves, the elusive characteristics as a part of their roles and as a characteristic part of their business partners. The decision of adapting is the third educational goal, to overcome cultural differences is a big challenge for the students. The students experience that cultural identity is complex; it is much more than nationality or religion, this is the fourth educational goal according to Jameson.'

Within in this Cocktail Party Simulation, which the author calls 'Teamwork within different Cultures and Values (TeCuMa) aiming more on the content of the game, the different parties are planning a joint venture. These parties signify different companies having a different -fictive- cultural background. The three company want to build a hotel including a shopping center. Therefore, one company symbolizes the bank, handling the financial interests, another one is the hotel company, developing and managing the property, and the third company deals with the construction itself. All three companies symbolizes different cultures. The joint venture is a compulsory decision. The cocktail party is the first meeting of the managers of the three company, and it is the beginning of working together. The lecturer decides about the group leaders (vice presidents). The vice presidents get the responsibility to prepare themselves and their teams for participating in the cocktail party and to develop a strategy of negotiation. The hotel company is the host. Each team (company) gets just its description of culture and values and no additional information concerning the other cultures. The students have to fulfil two tasks when preparing for the party: they have to generate their business concepts and at the same time they have to get used to their culture, which they have to present during the cocktail party. During the party they get an additional task: the have to interact with unknown and very different cultures and business concepts. The three groups represent different cultures and, which is more important for the joint venture, different interests. Therefore, they are in competition to each other, but have to reach a mutual goal at

the same time. During the cocktail party the different managers (students) interact with each other. They play their cultures, but may not talk about them. The cultures lead to high barriers and it sometimes even seems to be impossible to establish any relation or to compromise. Thereby, the students experience the contradictions. Sometimes a group gets so angry that the students leave class, but usually comeback after a while and try again.

At the end of the game a feedback and discussion is carried out. The different cultures are discussed and the handling of different cultures as well as possibilities of interaction. The decision making and compromising within this game is a great challenge, the question who adapts whom sometimes is impossible to answer.

Chances and Limitations

The games are used to train different competencies. Table one offers an overview on the games and the related success factors. The games are used consecutively to improve the number of trained success factors.

Success factor	**L ego**	**E feU**	**TeC uVa**	**Comments**
leadership	X	X	X	If necessary more training, evident improvement
Team ability Team work	X	X	X	Sometimes there are students who are unable to work in a team
Distribution of roles acceptance of roles	X	X	X	Enthusiasm of gaming , taking leadership, while having a different role
Self - management Time- management	X	X	X	After first negative experience, great improvement
Estimation of potentials Perceptions of limits	X	X	X	Enthusiasm leads to overestimation, improvement
dealing with time and competition pressure	X	X	X	Enthusiasm of gaming and of competition leads to neglecting aims, improvement
Estimation of alternatives Evaluation of consequences		X	X	Great improvement
Evaluation of information		X	X	Great improvement
Risk management awareness of imponderability		X	X	Enthusiasm of gaming leads to neglection of risks, great improvement
Networks Synergy effects		X	X	Difficult within Bachelor education
Mandatory co-operation expected difficulties			X	Difficult within Bachelor education, improvement
Intercultural competence			X	awareness, special trainings required

Tab. 1: Success factors related to Serious Games

Regarding to all games an atmosphere of confidence between students and lecturer is compulsory. The students need to get themselves into the game having the confidence to be within a protected area, this means an area where they can game without inhibition, without fear of failure.

Conclusions

Serious games are a new and seldom used methodology to train knowledge and competences. They combine gaming and learning at the same time. Serious games offer simulated problem situations involving the students intensively by forcing them to participate. At the same time the students are aware of being apprehensive of individual consequences or failures.

The three serious games being described in this paper are applied consecutively. This leads to the result that the success factors leading to management skills are trained consecutively as well. The undergoing, the experience of specific situations and their solutions as well as the reflection of the process afterwards support the learning process. Sure, there are limitations for the application of serious games like support and supervision, necessary time and class rooms, limited number of participants as well as gender issues and cultural background of the participants.

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