Published in: de Vries, Marc J.; Fletcher, Stefan; Kruse, Stefan; Labudde, Peter; Lang, Martin; Mammes, Ingelore; Max, Charles; Münk, Dieter; Nicholl, Bill; Strobel, Johannes; Winterbottom, Mark (eds.), *The Impact of Technology Education: International Insights.* Münster; New York: Waxmann, 2020, S. 63- 84. www.waxmann.com

Christian K. Karl & Heide Lukosch

Increasing decision making competencies by applying simulation and gaming in technology and engineering education

1. Introduction

Technology and Engineering (T&E) education is mainly driven by applying empirically based methods and procedures to solve technical problems. Even if decision making is one of the most prominent fields of activity in the T&E work environment, educational frameworks and curricular are often not addressing this issue. However, students in these fields have to adopt this competence in order to be able to analyse requirements, and take e.g. design, planning or management decisions related to technical and social challenges. Students contribute to the design of systems, which themselves become more and more complex (de Bruijn & Herder, 2009). Decision making processes have to be able to address the complexity and uncertainty in such systems, for example in transportation, energy, or ICT systems. Thus, T&E students should learn about complexity and ways to address it in decision making. Simulation games are a valuable way to communicate about and 'play' with complexity (Duke, 1980) and to train decision making. Students as players can explore effective decision making and experience the consequences of different decisions in a quasi-realistic setting, but without real consequences for their career, compared to the work place. This way, they do not only learn about decision making in a theoretical way, but can put theory in practice and evaluate different approaches. This chapter shows that not only in playing games, but also in designing them, students can learn about decision making in a ludic setting. First, requirements for decision making processes in complex systems have to be translated into a game design, and therefore, have to be well understood. Secondly, for the game design itself, decisions have to be made, often in an (interdisciplinary) team. This exercise helps students to develop decision making skills on different levels. Based on our studies, we conclude that the use of simulation games as learning instrument and design process shows its value in T&E education when behavioural skills such as decision making have to be adopted. Finally, we formulate a number of

recommendations for teachers and facilitators who aim at using games and game design as learning process, too.

2. Methodology

The authors conducted lab experiments by using different simulation games and game design approaches in a variety of occasions in T&E education. Based on this, evaluations and analysis regarding a) the learning experience of the students, b) the teaching experience of the teachers / facilitators, and c) the effectiveness of the chosen method, were made. Additionally, in the second case, the students were asked to self-reflect on the course and especially on how they experienced the chosen method of designing a game, and how they think this method affected their learning process.

The first case deals with the engineering and construction industry. In this industry, conflict and strategic interactions between project owners and contractors are very common (Levitt, Wang, Ho & Javernick-Will, 2011). Based on this, the game used in this case includes a variety of different parties acting against each other. Hence, this case employs game theory, which can be defined as "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers" (Myerson, 1991). This theory is common in fields like economics and business, political science, computer science, and philosophy. In this case, it is used as a multiplayer decision theory where the decisions of each player affect the payoffs to other players, and the players take this into account in their decision behaviour (Sejwal, 2014).

The second case discusses how the structured design process of a simulation game can help graduate students in developing skills to understand complex systems, and design or support related decision making processes. A group of more than 100 students designed their own games, related to management challenges in technology-driven organizations. The Triadic Game Design (TGD) method (Harteveld, 2011) has been used to structure the game design process, and to focus on the realistic aspect of decision making. All students were asked to provide a written reflection on the exercise, allowing us to qualitatively evaluate the value of the game design process as learning instrument.

3. Decision making competencies in technology and engineering

The increased complexity of today's society affects the work force, too, who face more complex assignments, and have to deal with a complex environment, for example interconnected organizations that heavily rely on advanced technologies. Due to increasing dynamics, interconnectedness and the role of technology in today's societies, more components in people's lives and work are getting more complex (Heylighen, 2002). That has consequences for the need of decision making competences.

Universities as well as schools for Vocational Education and Training (VET) prepare students not just for professional life (and give them a basis for a successful career), they have to deliver qualified and competent young professionals for various economic sectors with a strong ability in decision making. Hence, educational institutions are responsible for the creation of an adequate and efficient workforce to support the relevant economic sectors in their development. In this respect, the aforementioned institutions are distinctive supporting elements in the human resource and organizational development of different industries. This is reflected both in the design of study programs and individual courses.

When it comes to technological and engineering systems, for example in the domains of construction, transportation and logistics, the complexity and uncertainty that comes with these systems represents an increasing challenge for decision making. For instance, as the worldwide transportation of goods has become more and more complex, decision making in this field has become more difficult, too. The interconnectedness of a world-wide trade system makes it hard to predict future developments, and consequences disruptions that occur on regular basis, do have on the system in a whole (Kurapati, Lukosch, Verbraeck, & Brazier, 2015). Disruptions can have large impacts on the whole transportation system; as for example longer waiting times in container terminals, or traffic delays, leading to safety issues. Traditionally, waterfall-like approaches towards decision making fall short in light of such uncertainties and interconnectedness, which require flexible decision making skills. Related to this, games and simulations are frequently used for professional training or academic education and knowledge building (Klabbers, 2001; Rafaeli, Raban, Ravid, & Noy, 2003; Wolfe & Bruton, 1994).

Especially the advantages of simulation and gaming (S&G) are important influencing factors for improving decision making competencies. In general, S&G is a bridge between activity and own knowledge in which it is possible for participants to fastly accumuluate experience (Crookall & Thorngate, 2009).

By the advantage, to facilitate the presentation of difficult business activities in S&G (Anderson & Lawton, 2008) the awareness of consequences of own actions will be increased (Chin, Dukes, & Gamson, 2009), finally making it easier to promote decision making competencies. By conducting S&G, the discussion about the content and the method of learning will be stimulated (Fortmüller, 2007), which promotes cognitive and affective learning (Wilson et al., 2008). This results in a change of own attitudes in the long term (Chin et al., 2009), an important factor in improving decision making competencies. Additionally, S&G provides the opportunity to reflect problems from a different perspective, with which the participants compile several arguments / facts and finally conclude the best result (Fortmüller, 2007). By this, the participants can improve their awareness of developments (Wilson et al., 2008) as a further prerequisite for improving their decision making abilities.

Besides this, S&G is a safe alternative to train professionals and soon-to-be professionals where decision skills during disruptions can be enhanced without heavy cost implications (Dumblekar, 2004). S&G support actors in changing existing systems as well as in developing new systems, as they enable participants to deploy new collaborations, interactions, and decision spaces.

Therefore, S&G allow for deep insights in existing systems, and are able to make participants aware of related challenges and problems (Lukosch, Groen, Kurapati, Klemke, & Verbraeck, 2016).

4. Introduction to the employed approaches

This chapter gives a brief introduction of the employed approaches. The chapter follows a two-folded structure. The first part deals with the educational training environment "Construction Giant" and the second part with the Triadic Game Design Approach as Learning Process.

4.1 Case 1: The educational training environment "Construction Giant"

S&G allows to promote learning as well as to conduct experiments with sociotechnical systems and is already used to investigate e.g. bargaining power or as a research tools for testing social theories (Noy, Raban, & Ravid, 2006; van den Hoogen, Lo, & Meijer, 2014; Zúñiga-Arias, Meijer, Ruben, & Hofstede, 2007).

Due to the fact that the development of computerized simulation games lead to extensive cost (Wilson et al., 2008) and that manual games can be even successful (Andlinger & Greene, 1958), a round-based board game was developed for the first case. The game can be used in both VET and academic education. Besides the lower costs, a particular advantage is that board games can be conducted independently of IT infrastructure at almost any location. The detailed theoretical background of this game is introduced in Karl (2012). A detailed example for the integration of this game into a course is described in Karl (2013).

The general educational objective is that participants apply previously acquired knowledge and techniques in the field of construction and business management within the educational training environment. Further, the following mandatory skills are addressed within the game: a) decision making skills, b) analytical thinking and creativity, and c) communication / negotiation skills.

Each student operates his own virtual construction company. This construction company has to prevail against other participants on the construction market. Hence, the participants play a competitive game with a low bid method ('reverse' auction). Referring to Ioannou & Awwad (2010) this is the most common bid method for construction contracts in the U. S., as well as in Germany, and in many other countries in the world.

In the modelling of the game elements company, product, and market on the one hand, the principle of reduction (Stachowiak, 1973) is appropriate; on the other hand, a sufficient realism must remain. In this regard, the Johns Hopkins University Academic Games Project at the Center for Social Organization of Schools performed under the leadership of James Coleman a comprehensive assessment of gamed simulations in the early sixties (Boocock, 1994). This research showed that gamed simulations could be effective as teaching tools, but to result in effective learning outcomes, the activity must have a connection to reality. This point is particularly important for the encouragement of decision making abilities. As a result, the individual elements of the game are developed indeed simplified, but as tangible as possible to create a realistic environment for decision making in the classroom.

4.2 Case 2: Triadic Game Design Approach as learning process

The Triadic Game Design Philosophy (TGD) describes an approach towards game design along the elements of a) reality, b) meaning and c) play of a game (Harteveld, 2011).

As already mentioned in case 1, the 'reality' element of a game represents its model of reality and should, according to Harteveld (2011), be tighter in games with serious purposes, for example simulation games for learning. The reality of decision-making being a complex process with a number of actors involved, can be represented with different models, and then transferred into a game design. Especially the characteristic of a game with a number of players, interconnections, and an uncertain future, allows for its use when decision-making is the learning goal.

The 'meaning' of a game is connected to the creation of value through the game, for example the specific learning goal. It is related to the purpose of the game, or the goals the game needs to achieve, the strategy used for achieving this purpose, concrete operations that have to be taken in order to achieve the purpose, and the context in which the value creation takes place. In our case, students were asked to create a meaningful, game-based exercise on a technology-related problem they were interested in. This way, the workshop addressed their decision-making skills in its process. The meaning of a game can also include decision-making processes in a technical case, and many of the game ideas developed had a strong decision-making component. Thus, students had to study decision-making as a challenge, and had to explore how to transfer it into a meaningful game design.

The last element, 'play', is to make sure that an enjoyable and engaging experience is provided. Thus, a game designer has to define each step in a game, starting from a high-level aim up to each action a player can take within the game. Aside from its relationship to reality and meaning, a game represents a medium or a tool with specific characteristics and elements that immerse people in an interactive, fictitious scenario. In designing a good, playable and effective simulation game, all three elements are equally important (Harteveld, 2011). In our case, the focus of the learning process was less on this element of games, as we wanted the students to gather a proper understanding of the reality and the meaning, both related to decision-making in technical contexts. Yet, the fun element also refers to challenges, to game mechanics, and elements that can be used for players to engage in, understand, and design decision-making processes. Students had to look for ways how to translate the realism of their chosen case, together with the purpose of the game, into an engaging, playful exercise.

In summary, the TGD approach is suitable for designing games in a learning context, as it represents a structured approach towards a game design. This structure can be used to organize a learning process, where students subsequently work on issues related to the reality, meaning, and play aspects of a game design. Writing up a design documentation on this process enables students to critically reflect on the process, thus enhancing the learning process.

5. Application of the approaches

The following chapters describe the application of the employed approaches. As before, the first part shows details about the used board game "Construction Giant" and the second part how the Triadic Game Design Approach was employed.

5.1 Case 1: "Construction Giant" as training method in construction technology

This self-developed round-based game (each round corresponds to a quarter of a year) is equipped with:

- Game board (illustration of a city with road infrastructure)
- Project cards (reflecting different contracts based on public, private and single tenders)
- Event cards affecting individual companies, projects and the whole market
- For each player a pawn and 15 wooden houses in an individual colour
- Each player different tiles for resources: 30 black tiles (own staff), 20 blue tiles (own equipment)
- For the whole game:100 red tiles (rental equipment)
- Various forms (e.g. offer sheets, joint venture contracts)
- Bank notes for each player
- Different cubes for generating uncertain events (one cube with numbers 1 to 6 and one cube with numbers 1 to 3)

To avoid decisions considering the near end of the game, which will result in unnatural, irregular behaviour, the numbers of quarters to play was not communicated as a predetermined number at the beginning.

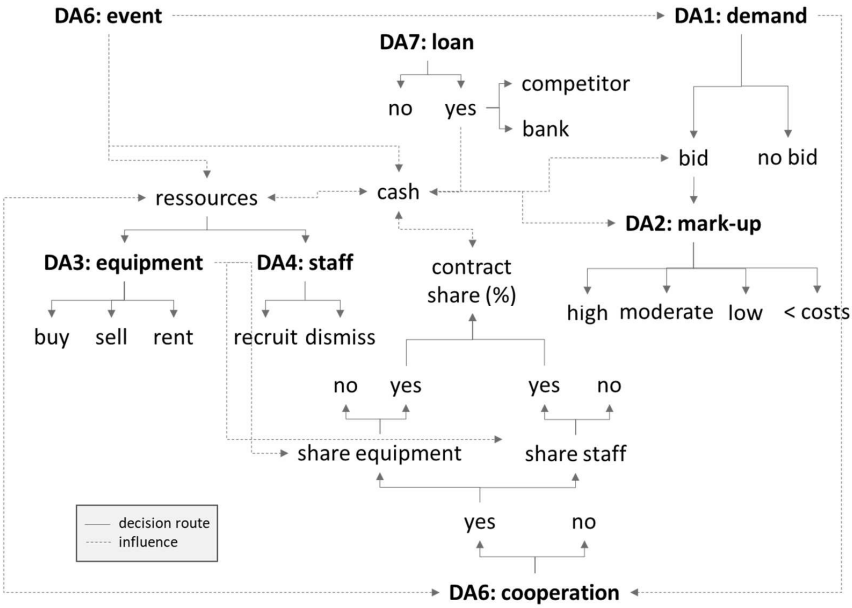

Figure 1: Decision Areas (DA) and their relation to each other

5.1.1 Included decision areas

The game model addresses seven Decision Areas (DA, ref. figure 1). Demand (DA1) is represented by pre-sorted project cards. Through this arrangement, the probabilities of tenders will be affected. The native set of project cards contains about one-third from each tender type. By pre-sorting of the used project cards to a specific deck, a market development can be emulated. Because of this variation the participants have to monitor the market continuously. They have to respond to current trends and estimate future situations.

The game sessions included in this case study were focusing on leading a company, not calculating projects in detail. Therefore, construction costs were given, only risk and profit were chosen as meaningful mark-up decisions (DA2). Equipment (DA3) can be bought from the market or from competitors. It can also be sold in the same manner. The price has to be negotiated with the competitors in the game. The market has his own fixed prices. The available rental items in the case was 100 tiles, which means an "infinite" rental equipment market.

Staff (DA4) can only be obtained from the market (black tiles). It can also be dismissed. This results in firing costs which are not insignificant (this

includes a social component within the game design). Corresponding to the learning objectives, the necessity to form joint ventures (DA6) will encourage the willingness to communicate and the negotiation and conflict resolution skills of the participants.

If competitors want to share equipment and staff in a project, a joint venture contract (JV) has to be used. The negotiated interests for each party are fixed in this contract. These shares are treated for both the expenditure and revenue as well as for the offering expenses. The JV is considered as one bidder for the project. In the presented study three event categories (DA6) are included. They affect: market demand (DA1), resources (D3 & D4) and cash (as a result DA2) in projects or for the whole company.

If a company needs more cash (for investment or if it is near to insolvency), two options for loan (DA7) are possible: a) a competitor makes a loan or b) the bank makes a loan (role of the bank is played by the facilitator). These alternatives were already communicated before the start of the game. If a loan is awarded, an agreement was negotiated between the parties. The contents of the agreement such amount of the loan, repayment and interest rate are fixed in the contract.

5.1.2 Student groups and process

In this case a multi-actor behaviour experiment with 55 participants was designed to stimulate the required behaviour under different conditions. The participants were students in the Bachelor Program for Civil Engineering and the Master program in Construction Management both at the University of Duisburg-Essen.

Each game board represents a city in which up to six persons can participate as building contractors. The students freely formed for each board one group with up to 6 persons. Every participant takes over the role of general manager as well as project manager of the own construction company. As a consequence of these roles, the participants are continuously moving within a dynamic triangle consisting of market, company and project. Mandatory tasks that require in particular decision making skills are a) work preparation, b) resource planning, c) costing and cash flow planning and d) market monitoring. Related content which is necessary for performing the tasks was already taught in previous lectures.

In session B1 an amount of 33 Bachelor students participated in 6 groups with 5–6 each. They played the game up to 6 rounds in around four and a half hours. Session M1/A (22 Master students in 4 groups with 4–6 each) and session M1/B (21 Master students in 4 groups with 4–6 each) consist of

the same group of students who played the game two times up to 7 rounds in around four and a half hours. Beside the aim of investigating decision making behaviour the additional aim of this setting was to study the implementation, manageability, acceptance and learning outcome under different conditions. Hence, the basis of the present case comprises data and experiences from three sessions consisting of 76 datasets. At the end of the sessions no standardized examination was provided.

5.2 Case 2: Triadic Game Design as teaching method in Management of Technology

In this case, not a pre-designed game was used to support students in adopting decision making skills, but a game design process was the methodological approach. The Triadic Game Design (TGD) philosophy (Harteveld, 2011), as shown above, represents a structured concept towards game design. It describes the combination of the three worlds of reality, meaning, and play, a game design should balance in order to offer a valid, meaningful, and engaging experience. The TGD approach was used in a class of 102 undergraduate students in an engineering program. These students follow a program that combines engineering skills with management competencies. Thus, decision making competencies towards engineering artefacts as well as managerial choices are key skills for these students. The class the TGD method was applied to, was held at the end of the first year of this program. The class is called "Integration Moment", representing a possibility for the students to reflect on the first year of the educational program, to integrate what they have learned, and to apply the knowledge gathered to realistic cases. To support this process, the main assignment in this class is to develop a game along the TGD structure. The students are free in choosing a case, yet it should represent a managerial challenge in an engineering environment. Students are asked to mainly focus on the reality aspect, thus to gather a good understanding of the system, the stakeholders involved, as of the problem or challenge the game (concept) will address. This is a common approach in management of engineering education. Yet, the relationship to a realistic case, and the combination with the creative work of game design represents an innovative learning approach.

5.2.1 Student group and process

102 students participated in this class, divided into 25 groups of 4–5 students each. 84 students were male, 18 students female. All students got the same introductory lecture to the TGD method. Work sheets on the three elements of reality, meaning and play were provided. Two experienced teachers with a background in game design from the same faculty the students belong to, guided the students through the whole process. The 25 groups had work group meetings for 2 hours each week. Feedback was given on group level. Lectures and expert discussions added to the learning experience. The assignment of the students included the development of a game design documentation and a short presentation of their game designs. Both parts were graded by the accompanying teachers.

6. Results and discussion

The results presented in this chapter are mainly based on the debriefings of the two cases. For gaming sessions, the debriefing is seen as crucial. It serves the purpose of training and education, during which participants learn and reflect on the experiences (Crookall, 2010; Lederman, 1992). Debriefing gives the participants space and time to recapitulate what happened during the game and to reflect on their learning experiences, and thus to gain a deeper understanding of the subject matter (Hill & Lance, 2002; Peters & Vissers, 2004; Kriz, 2010). Additionally, it provides insights into the decision making process and behaviour from the perspective of the learners.

6.1 Case 1: Board game as tool for improving decision making abilities

The evaluation of the course is divided into three elements: A) institutional evaluation, B) evaluation of the online-learning environment and C) individual evaluation of game. The debriefing of the conducted game is one of the latter.

The debriefing method considers the learning process as well as decision making based on participant experiences. It consists of the following elements: C1) pre-questionnaire, C2) post-questionnaire, C3) debriefing for each group (company level), C4) debriefing with the class, C5) assessment of course and facilitator quality, and C6) developing a formal construction

market model with the class. Based on C3 experiences and data from game plays were collected and four central dilemmas were identified:

- Dilemma 1: Am I going down with the price or not? (47.06 %)
- Dilemma 2: Do I dismiss employees now or later? (8.82 %)
- Dilemma 3: Will I sell equipment now or later? (4.41 %)
- Dilemma 4: Continue acquiring projects or reduce the company substance? (1.47 %)

In particular, dilemma 1 was strongly connected to the market development which was often discussed by the participants in the debriefing. Inadequate development of the own company was frequently justified with an unfavourable market trend or dice pitch. While it is acknowledged that the market development is also a result of the behaviour of the participants (mainly through price competition), nearly anybody admits to have been involved in savagely price competitions.

Dilemmas 2 and 3 are related to steadily increasing financial losses and as a result limited cash. Most of the participants kept too long unneeded workers and equipment. The decision to keep the company competitive through healthy shrinkage was mostly made too late.

Based on the aforementioned dilemmas and deeper discussion, the students communicated the following problems in decision making:

- Technical incompetence (incorrect calculation of projects over time) (13.34 %)
- No problem in own decision making → It's always someone else's fault! (10.29 %)
- The consequences of the decisions are not clear at first glance. (10.29 %)
- Will I wait until I have collected and evaluated all the information? When do I have all the information? (2.94 %)

As a result of the debriefing process obstacles in decision making were identified and during further discussion possible mitigation actions were developed with the students.

Table 1: Obstacles in decision making and mitigation actions

No.	obstacle	mitigation
1	Fear of doing something wrong; inner insecurity	Better a bad decision than no decision, because absolute security does not exist. → Courage to decide
2	Fear of the challenges that arise from the decision	Identify challenges (tasks) and develop a realizable action plan.
3	Fear of the consequences	Every decision has an effect. → Foreseeing possible consequences reduces anxiety.
4	There are too many alternatives.	Develop an evaluation matrix.
5	The familiar is preferred, the unfamiliar / new will be avoided.	Habits are restrictive. → Courage to break new ground
6	Social / personal reasons, e.g. is it reasonable for other participants (colleagues, partners, friends)?	Consider the reasonableness of the overall system. → Step back to see (almost) all elements and connections.
7	All decision alternatives seem equally unattractive.	At the end, a decision MUST be made. → obstacle 1
8	Important people give me advice.	Important people are not necessarily those who are able to overview everything or have the necessary expertise. → Take responsibility.
9	There is a lack of important information to fully substantiate the decision.	NEVER all (necessary) information is available. → Include as much information as possible in the given time. → obstacle 1
10	What do the others think?	The "others" might decide that as well! → Break away from external influences.

Based on debriefing element C2 (post-questionnaire) the students have communicated that the game has made relationships in construction business more clearly for them (B1: 72.7 %, M1/A: 81.8 %, M1/B: 93.8 %). Additionally, in the self-assessment of advanced skills in decision making related to the decision areas presented before most of the students stated, that by playing the game, their competencies increased (B1: 81.8 %, M1/A: 90,9 %, M1/B: 90.48 %). Taking into account the external perception by the facilitator, there was no indication of self-overestimation by the students during the discussions in the course, which were very reflected and carried out in a technically correct and sound manner by the students. For this reason, it can be deduced that the implementation of the game has in fact led to an increase in com-

petence among the participants. The financial results of the companies show that in B1 36.4% of the companies finished with a negative bank balance. In M1/A there were just 18.2% and in M1/B only 4.8%.

Considering this in relation to the question of the advanced understanding of relations in construction business and the advanced skills, it leads to the assumption, that there might be a connection. Interesting in this regard is also, that it seems that the group M1 was able to expand the already gained knowledge by played the game a second time. However, the small amount of data sets does not give any further clues.

Foremost from group B1 there came the recommendation to prohibit making offers underneath production costs, which was used in some occasions as a strategic measure. Even it is fully understandable, that the other competitors condemn such behaviour, which is also disadvantageous or even dangerous for a whole market, the possibility to make such offers is an important element of the construction reality. In particular, understanding this context and learning from it is a very important step in the decision-making process.

A further recommendation was to provide an excel sheet for the calculation and management of the projects. This should save time which could be used for more rounds. Based on this recommendation an improved version of the game is currently in development.

In summary, the general aim of increasing decision making competencies and to make relationships more clear were achieved in all three sessions. Nearly every participant would play such a game for a second time or would recommend it to future employer.

6.2 Case 2: Triadic Game Design workshop as educational structure for decision making

From a teacher's perspective, the TGD method worked very well as structuring method for the learning experience. Especially the work sheets for each of the three elements are a good support for what the students should work on. Most of the groups followed the sequence and elements the work sheets prescribed. They focused on the system, the relevant stakeholders, and the problem first. For doing so, they made use of additional materials and approaches, such as systems analysis methods. This way, they identified major decision relations within the system. In addition, they had to take decisions in a team context. Thus, decision making was both studied within the engineering case as well practiced within the assignment.

Students were asked to include a brief reflection on the chosen method in their final documentation. The majority of the groups valued the TGD

approach in this class positively. "We very much enjoyed this exercise and had a lot of fun using our creativity to come up with an unconventional game design", was one comment from a group. Yet, it was also stated that balancing the three aspects of the TGD approach was challenging:

> "One dilemma that comes forth from the Triadic game design and that also played a role in this case, was the tension between reality and meaning. In order to specify a proper meaning, a sufficient representation of reality is needed. However, here also lies the risk that only the aspect of reality which supports the meaning would be taken into consideration."

Another group mentioned that "This was a very interesting project and the approach of this course really pushed you to think outside the box." In this group, the work on the play aspect was especially appreciated, stated as:

> "Integrating all our knowledge into one project: it was very interesting to see how all the MOT (Management of Technology) subjects are interwoven. I had smart, hard-working team members with good ideas. I liked the subject that was chosen and think it was a good choice, everyone seemed to like the idea of frugal innovation; half of our group is from India as well, so they provided us with invaluable information and context. The reality and meaning part more or less followed what was known, but the play element really challenged our thinking, which is also where I contributed in the project."

Another team member of this group also mentioned that

> "This course made me realize the importance of gamification to overcome challenges faced by an organization and to build on an existing knowledge base. Through this course, I was able to explore various concepts in MOT through a different perspective. This assignment not only created an interest for me in gamification but also improved my skills to work in a team."

Another group member said that

> "I have found this assignment very interesting and motivating since it gave us the opportunity to apply all the knowledge we have learnt in the first year of the Master in a real case. The most tedious part was choosing the topic since we were a little bit lost at the beginning, but after that we started working very efficiently thanks to the good environment within the team and the predisposition to collaborate and help each other."

In addition to the mainly positive feedback, recommendations for further improvement were also mentioned, such as:

> "A last point I want to raise is more a recommendation. I believe that the Triadic Game Design approach is a very valuable and good one for this course. However, I believe that the worksheets and the three lectures are insufficient for most

> people to completely grasp how the different parts are interwoven and, together, come to a valuable outcome. I would recommend providing more knowledge and structure on the interplay between not only the three elements (reality, meaning and play) but also their sub elements."

It shows that the secondary goal of teaching the engineering students decision making skills by the assignment and the teamwork itself, was also mentioned by some of the students:

> "The brainstorm sessions designing the game gave us chance to exercise our creativity and critical thinking and the outcome was gratifying. For each of the worksheets, the ideas were and then divided the work amongst us allowing for offline collaboration where needed. The end result is the comprehensive report that we all contributed to."

Another group reflection confirms this learning:

> "We carried out the 'Integration Moment' assignment with a project-based approach: division of roles was instrumental to plan and coordinate the overall work [. . .] Doing a project of such magnitude, integrating all the knowledge learnt in the first year of the MOT programme, was really challenging and stimulating. I learnt how to carry out a project which entails the coordination and confluence of different people, knowledge and culture. This further improved my team working skills and time management, as well as hard skills related to MOT fields."

While the assignment of developing a game design concept in general was positively evaluated, it was challenging to make the students focus on the system and the problem, as was the main aim of the assignment from an educational viewpoint. Many students rushed to the creative decisions related to the play aspect. The teachers had to stop and advise them to first work out the details of the system, involved actors, and the problem before heading to think about technologies and elements of the game play.

Some groups also struggled with the creative part, and weren't able to move away from the real system to a playful translation. Yet, with the grading it was taken into account that the students were unexperienced game designers, and the work on the reality and meaning aspect was weighed heavier than the one on the play elements in the final grading.

In summary, using the TGD approach had both advantages and disadvantages. An advantage of this method is that the students face a different assignment than writing a report only. A limitation of the method is the focus on the creative game design, as it might represent a disadvantage for students who only have limited creative skills. The game design aspect can also distract from the original assignment of analysing an engineering case, and its decision structure.

The game design workshop is used as structure for a course in higher engineering education. Students have to apply skills and knowledge from their educational program to engineering cases, and develop a game concept as solution. Not only does this approach support the reflection, application and integration of the skills that are related to the formal educational program the course is part of, but students report in a majority that the game-based approach enabled them to improve their project management, communication and collaboration skills. As the game design workshop is demanding both in time as in capacity, students retorted that they had to develop and apply time management skills, too.

For the teachers, the structure worked well, as its provides students with a well-defined way of stakeholder, system, and problem analysis, definition of the aim of the intervention (game), and its implementation. These aspects are combined with a creative assignment of not only thinking of a random intervention or advice for an organization, but how to translate this into an engaging and interactive game-based exercise. This part of the assignment is especially appreciated by a large group of students, as the feedback shows.

Yet, in this example, it was clear that the focus would not lie on the creative design, and that the problem analysis and purpose definition would be more important for the given assignment. While some students struggled with the transfer of the problem into a game context, no group reported that this detoriated (the learning experience. In general, we can summarize the qualitative feedback of the students into advantages and disadvantages or challenges of using TGD as structure in engineering education as follows:

Table 2: Advantages and Challenges of using TGD as structure in engineering education

Advantages	**Disadvantages/Challenges**
Engaging learning experience	Demanding in time and effort (students)
Beyond formal learning goals	Teachers have to be familiar with the method and with games as intervention in engineering contexts
Fosters team work, decision-making, and communication skills	Does not allow for individual performance in case students aim to stand out
Practical assignment enables discussion about aspects of the engineering education program	Creative, 'fun' aspect can overrule the focus on problem and purpose
Well-defined course structure along the themes of reality, meaning and play	Introduction to game design method and games in general is only superficial
Guidance with worksheets, detailing the three themes of reality, meaning and play	Students with interest in games might have an advantage in the assignment

7. Conclusions

Due to the fact that the feedback from the participants was positive, shows that simulation games for T&E education may be well appropriate. The game (design) approaches in both cases are well accepted from the students due to their realistic design, which permits a wide acceptance and increased motivation.

In both cases participants commented that they have heard a lot of theoretical content before, but now they can use this in practice and understand more clearly the meaning of what was first transferred in a more theoretical way. Students said that they finally understood both theory and application of the different topics. In particular, the relationships within the construction industry in the first case and the consequences of insufficient decision have been particularly aware of. During the discussions, the participants showed that they achieved most of the required competency goals in both cases. In the case of applying TGD, students were happy that they could put their theoretical knowledge into practice. The use of the TGD approach not only enabled the students to reflect on decision-making as a skills, but also to put their decision-making skills into practice during the challenging design process.

Dealing with decision making processes is always related to human behaviour due to the fact, that decisions are a result of the latter. Here, context is important (Luke, 2004). Identical choices in games result in different behaviour and decisions when they are framed differently or conducted in different contexts (Kahneman & Tversky, 1979). This was also obvious in session M1/B of case study 1 were the students played two times the game. Therefore, describing the environment in which a person makes decisions plays a critical role in studying and understanding influences and results of the made decision as well as the learning processes necessary for this.

Collecting context-related data can significantly help to draw a picture of the sphere in which different decisions were made. The application of S&G as a data-gathering tool can be a valuable tool in this regard. Meijer and his colleagues proved that it has been possible to test hypotheses using data gathered in gaming sessions (Meijer, Hofstede, Omta, & Beers, 2008) and a database driven solution enables researchers to collect decision related data continuously (Noy, 2014). This also applies to the use of a structured game-design method as TGD, that motivates students to collect data about a given topic, such as challenges and decision-making in complex, technlogu-related problem settings.

Even though the board-based game 'Construction Giant' as well as the use of TGD for game concepts have been a successful and valuable experience for

students so far, there are evidences, that online database-driven games can play a more vital role in teaching and learning situations as part of blended learning scenarios. The latter is a combination of traditional and online teaching and learning methods (Lang, 2006). In this context, blended learning scenarios will benefit by including S&G as a further teaching and learning method, especially when following a science-based, accepted method such as the Triadic Game Design Approach (Harteveld, 2011).

References

Anderson, P. H., & Lawton, L. (2008). Business Simulations and Cognitive Learning. *Simulation and Gaming*, 40 (2),193–216.

Andlinger, G. R. (1958). Business games – play one! *Harvard Business Review*, 36 (2), 115–125.

Boocock, S. (1994). The Johns Hopkins games program. *Simulation & Gaming*, 25, 172–178.

Chin, J., Dukes, R., & Gamson, W. (2009). Assessment in Simulation and Gaming: A Review of the Last 40 Years. *Simulation and Gaming*, 40 (4), 553–568.

Crookall, D. (2010). Serious games, debriefing, and simulation/gaming as a discipline. *Simulation & Gaming*, 41 (6), 898–920.

Crookall, D., & Thorngate, W. (2009). Acting, Knowing, Learning, Simulating, Gaming. *Simulation and Gaming*, 40 (1), 8–26.

De Bruijn, H., & Herder, P. M. (2009). System and actor perspectives on sociotechnical systems. *IEEE Transactions on systems, man, and cybernetics – part A: Systems and Humans*, 39 (5), 981–992.

Duke, R. D. (1980). A paradigm for game design. *Simulation & Games,* 11 (3), 364–377.

Dumblekar, V. (2004). Management Simulations: Tests of effectiveness. Online posting on *Simulation & Gaming: An Interdisciplinary Journal of Theory, Practice and Research* (online only). http://www.unice.fr/sg/resources/articles/dumblekar_2004_management.htm

Fortmüller, R. (2007). Learning Through Business Games: Acquiring Competences Within Virtual Realities. *Simulation and Gaming*, 40 (1), 68–83.

Harteveld, C. (2011). *Triadic game design: Balancing reality, meaning and play*. London, Dordrecht, Heidelberg, New York: Springer.

Heylighen, F. (2002). Complexity and information overload in society: Why increasing efficiency leads to decreasing control. *The Information Society*, 1, 44.

Hill, J. L., & Lance, C. G. (2002). Debriefing stress. *Simulation & Gaming*, 33, 490–503.

van den Hoogen, J., Lo, J. C., & Meijer, S. A. (2014). Debriefing in gaming simulation for research: opening the black box of the non-trivial machine to assess validity and reliability. In A. Tolk, S. D. Diallo, I. O. Ryzhov, L. Yilmaz, S. Buckley, & J. A.

Miller (Eds.), *Proceedings of the 2014 Winter Simulation Conference*, 3503–3516. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Ioannou, P. G., & Awwad, R. E. (2010). Below-average bidding method. *Journal of Construction Engineering and Management*, 136 (9), 936–946.

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An analysis of decision making under risk. *Econometrica*, 47, 263–291.

Karl, C. K. (2012). Additional Benefit Through Competency-Oriented Business Simulations. In J. A. Smith (Ed.), *Developments in Business Simulation & Experiential Exercises,* Association for Business Simulation and Experiential Learning (ABSEL), San Diego (pp. 35–46).

Karl, C. K. (2013). Integrative Learning: Exploring Opportunities in Business Simulations. In J. A. Smith (Ed.), *Developments in Business Simulation & Experiential Exercises,* Association for Business Simulation and Experiential Learning (ABSEL), Oklahoma City (pp. 48–57).

Klabbers, J. H. G. (2001). The emerging field of simulation & gaming: Meanings of a retrospect. *Simulation & Gaming*, 32, 471–480.

Kriz, W. C. (2010). A Systems-oriented constructivism approach to the facilitation and debriefing of simulations and games. *Simulation & Gaming*, 41, 663–680.

Kurapati, S., Lukosch, H., Verbraeck, A., & Brazier, F. M. (2015). Improving resilience in intermodal transport operations in seaports: a gaming approach. *EURO Journal on Decision Processes*, 3 (3–4), 375–396.

Lang, M. (2006). Blended learning. In F.-J. Kaiser & G. Pätzold (Eds.), *Wörterbuch Berufs- und Wirtschaftspädagogik*, 2nd edition (pp. 195–196). Bad Heilbrunn: Klinkhardt.

Lederman, L. C. (1992). Debriefing: Toward a systematic assessment of theory and practice. *Simulation & Gaming*, 23 (2), 145–160.

Levitt, R. E, Wang, C.-M. A., Ho, S. P., & Javernick-Will, A. (2011). *A contingency theory of organizational strategies for facilitating knowledge sharing in engineering organizations*. Working Paper #64, submitted to Engineering Project Organization Journal, First draft.

Luke, D. (2004). *Multilevel modeling*. Thousand Oaks, CA: SAGE Publications.

Lukosch, H., Groen, D., Kurapati, S., Klemke, R., & Verbraeck, A. (2016). The role of awareness for complex planning task performance: A microgaming study. *International Journal of Game-Based Learning (IJGBL)*, 6 (2), 15–28.

Meijer, S. A., Hofstede, G. J., Omta, S. W. F., & Beers, G. (2008). The organization of transactions: research with the Trust and Tracing Game. In *Conference Bulletin, Proceedings of the 8th International Conference on management in Agrifood Chains and Networks, Ede, The Netherlands, 28–30 May 2008* (pp. 38). Wageningen: Wageningen Academic Publishers.

Myerson, R. B. (1991). *Game theory: Analysis of conflict*. Cambridge, MA: Harvard University Press.

Noy, A. (2014). A computer-assisted educational auction simulation. *Simulation & Gaming*, 45, 371–393.

Noy, A. Raban, D. R., & Ravid, G. (2006). Testing social theories in computer-mediated communication through gaming and simulation. *Simulation & Gaming*, 37 (2), 174–194.

Peters, V. A. M., & Vissers, G. A. N. (2004). A simple classification model for debriefing simulation games. *Simulation & Gaming*, 35, 70–84.

Rafaeli, S., Raban, D. R., Ravid, G., & Noy, A. (2003). Online simulations in management education about information and its uses. In C. Wankel & R. DeFillippi (Eds.), *Educating managers with tomorrow's technologies* (pp. 53–80). Greenwich, CT: Information Age Publishing.

Sejwal, R. (2014). Game theory and human behavior. *International Research Journal of Management Sociology & Humanity*, 5 (3), 360–364.

Stachowiak, H. (1973). *Allgemeine Modelltheorie*. Wien: Springer.

Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., Orvis, K. L., & Conkey, C. (2008). Relationships between game attributes and learning outcomes: Review and research proposals. *Simulation and Gaming*, 40 (2), 217–266.

Wolfe, J., & Bruton, G. (1994). On the use of computerized simulations for entrepreneurship education. *Simulation & Gaming*, 25, 402–415.

Zúñiga-Arias, G., Meijer, S. A., Ruben, R., & Hofstede, G. J. (2007). Bargaining power and Revenue distribution in the Costa Rican mango supply chain. *Journal on Chain and Network Science*, 7 (2), 143–160.

DOI: 10.17185/duepublico/78467
URN: urn:nbn:de:hbz:465-20230530-155203-6

Karl, Christian K. ; Lukosch, Heide: Increasing decision making competencies by applying simulation and gaming in technology and engineering education. In: de Vries, Marc J.; Fletcher, Stefan; Kruse, Stefan; Labudde, Peter; Lang, Martin; Mammes, Ingelore; Max, Charles; Münk, Dieter; Nicholl, Bill; Strobel, Johannes; Winterbottom, Mark (eds.), *The Impact of Technology Education: International Insights.* Münster; New York: Waxmann, 2020, S. 63- 84