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DEVELOPMENT OF AN EDUCATIONAL GAME TO TEACH INTEGRATED PROJECT DELIVERY PRINCIPLES

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ABSTRACT

Although IPD exists as a project delivery option especially for high complex buildings, the construction industry continues to use traditional approaches and methods for project delivery. The major barriers to the use of IPD are a general fear of change as well as a lack of knowledge and understanding. Educational games can be used to build knowledge and understanding. These games enable competence-oriented, experience-based, and motivated learning. Starting with the basics of game didactics, this paper describes the development of an educational game to teach IPD principles.

Existing educational games from the field of Lean Construction are used to convey an understanding of methods used in IPD. IPD cannot be reduced to a single method, the game developed takes a more holistic approach. Therefore, the game is intended to teach principles of IPD through experience-oriented learning and to show the necessary process of change that accompanies this type of project delivery. This is achieved by simulating a construction project that makes IPD principles easier to understand and more tangible. The participants independently gain experience in the field of IPD through active involvement and group reflection. The paper also includes experiences with first applications of the game.

KEYWORDS

lean construction, Integrated Project Delivery (IPD), action learning/research, educational game, live simulation game.

INTRODUCTION

Integrated Project Delivery (IPD) is increasingly gaining interest in some countries of Europe, such as Finland and Germany. IPD aims to optimize project execution as a whole so that projects are more likely to be completed with less conflict, within budget, and on time. To achieve this, IPD relies on, among other things, early integration of key stakeholders, joint risk management, and a joint incentive system aligned with customer

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goals (Ashcraft, 2010). In this paper, IPD refers to all integrated approaches to project delivery in construction projects.

Despite growing popularity, obstacles to the wider adoption of this approach persist. A major one is the general fear of change (Pishdad, 2012). Change involves the adjustment of behaviors and routines. It cannot be forced by simply providing information (Fench & Marrow, 1945). People need to be motivated to change (Steins & Haep, 2011).

Educational games represent an interface between the transfer of information and the implementation of theory (Thiele, 2020). In particular, we use the term "educational game" in the following to emphasize the educational nature. However, we still regard it as a synonym for e.g. "learning" and "simulation game". Applying or implementing theories generates motivation (Franken, 2019). Therefore, the goal of this paper is to describe the development of an educational game for teaching IPD. The educational game conveys the basic principles of IPD in a tangible way and thus eases the necessary change processes associated with IPD.

Figure 1 shows the approach used in our research. The following sections of this paper are based on this approach. The starting point of the investigations was a systematic literature research. Here, the aspect of the didactics of educational games was dealt with in particular. The development of an educational game is a creative process that requires innovative thinking. Therefore, two workshops were conducted. The participants in these workshops had different levels of knowledge in the field of Integrated Project Delivery. This creative process was structured with the help of the design thinking method. Through this, the needs of the client were put into focus (Osann et al., 2020). Clients in this case means the potential participants in the IPD educational game. The design thinking method is an iterative procedure for solving complicated challenges (Diehl, 2021). Workshops were planned and conducted using this method. Based on the results of the workshops, the educational game was developed and subsequently implemented and validated.

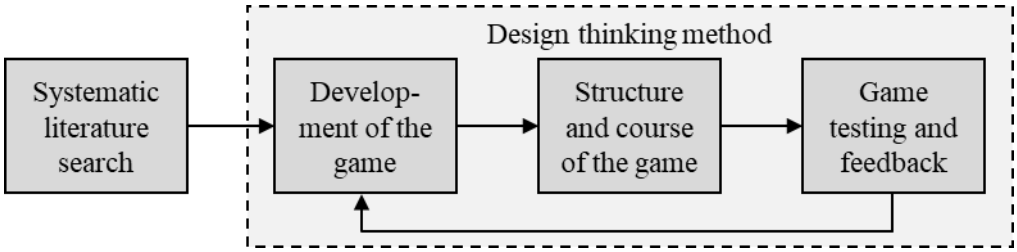

Figure 1: Game development approach

The game testing was intended to check the fit of the live simulation game with the requirements formulated in the research objective. The test was carried out with IPD experts as well as with IPD novices. This approach was chosen with the intent that on the one hand the experts check whether the necessary components of Integrated Project Delivery are taught, and, on the other hand, the novices check to what extent they build up competencies and an understanding of Integrated Project Delivery. IPD experts are familiar with the theory of this form of project delivery and have been or are involved in construction projects that have used Integrated Project Delivery.

DIDACTICS OF EDUCATIONAL GAMES

Didactics cannot be reduced to the science of teaching. It is a means for linking the contexts and structures at the level of the factual logic of a subject matter with the psyche of the learner (Siebert, 2012).

Learning is a cognitive process that is not immediately apparent from the outside. What can be observed is the behavior or action of the learner. The effects of the learning process are derived from these observations. From the pure observation of the learning results, however, no delimitation becomes apparent, what learning is concrete. There are different didactic ideas about this. One of these is instructional didactics. This says that the individual learning steps need in each case an impulse by the teacher. The teacher has a high proportion of speech and often intervenes in the learning process. The interaction with the learner is low (Hallet, 2009).

In the context of adult education, it is advantageous to place the topics to be taught in a concrete situational context. Especially for the teaching of behaviors, the learning content should be conveyed with the help of examples that relate to professional or social experiences already acquired by the learners. In this case, the learning process is perceived as meaningful by the persons, since the situations are personally known and the learning meaning becomes apparent. An important factor here is that the situations are perceived as realistic and authentic (Quilling & Nicolini, 2009).

In a simulated reality, as it is given in some forms of games, experiences can be gained without danger. A simulation aims to imitate elementary aspects of reality. Participants in the game can try out attitudes and strategies that are directly reflected upon (Kerres et al., 2009).

A simulation game has several characteristics. In general, situations are brought about, action decisions are demanded from participants and the effects of these decisions are examined. The setting can be based on a fictitious or real situation, and the objectives for the simulation are clear or implied. Participants are directly involved in the simulation and further development of situations is based on their actions (Holzbauer, 2008).

Figure 2 shows the correlation between the complexity of simulation games and the consequences for different parameters. With increasing complexity, the possibility of conveying larger amounts of information and depicting reality more accurately increases. The game stimulus also initially increases. However, the comprehensibility for the game decreases and has a negative effect on the game stimulus. The maximum learning effect for participants in a simulation game lies in a balanced relationship between the listed parameters. The complexity must not exceed a critical value, otherwise, the learning effect will decrease.

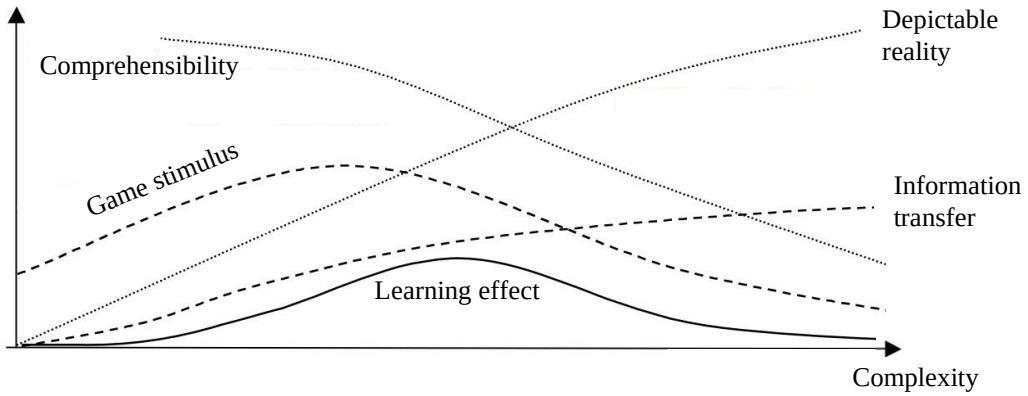

Figure 2: Complexity in simulation games (Holzbauer, 2008)

A simulation moves between a very abstract and realistic modeling. An exact representation of reality is not decisive in the learning of skills. The decisive criterion is an adequate didactic reduction of the real conditions. The model is brought into use and

interaction by playful elements. The freedom within the interactions is given by the rules in the game and the defined roles (Kriz, 2011).

The necessity of a didactic reduction exists when there is a high complexity of facts to be taught. A reduction can be understood as a simplification. This must be done appropriately. The interdependencies and structure of the processes in the subject matter must be preserved (Weinberg, 1991).

The simulation of reality represents the first dimension of simulation games. The reason for using a simulation is that bringing about a real situation is not possible for time, cost or safety reasons. The second dimension is the game. In simulation games, not only is a reality recreated but a reality of one's own is created. This created reality is often characterized by a kind of competition and follows certain rules. The third dimension is the roles. Players take on roles of actors and can represent individuals, groups, or organizations (Kriz, 2011).

The general procedure of a simulation game is composed of three phases. In the instruction phase, also called “briefing”, the participants are introduced to the game. The contents include, for example, the framework situation, the roles, and the rules of the game. The game phase is the active element. The participants have to act and react out of their role and the associated mental background. They work independently and can make mistakes that remain uncommented from the outside. In the reflection and evaluation phase, also called “debriefing”, the experiences in the simulation are consciously worked through. The content and emotional experiences of the participants are reflected upon. Closing the simulation early after the game phase leads to a low level of competence building. Conscious reflection and evaluation in the group is an essential component for skill acquisition (Birgmayer, 2011).

Figure 3 shows the three phases according to Klabbers (2009) as a game circle. Within a game there is the possibility to repeat the phases if necessary.

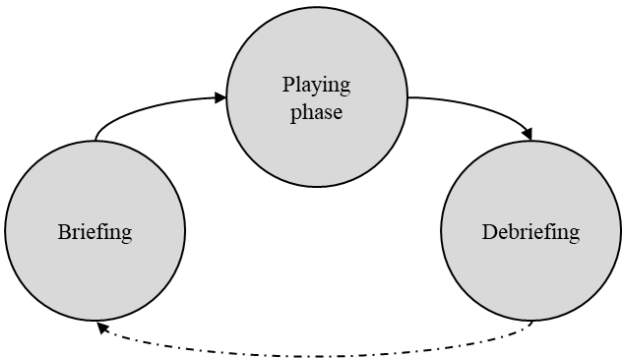

Figure 3: Simulation game course (Klabbers, 2009)

Interest concerning IPD and Lean Construction (LC) has increased over the last few years. Knowledge of LC is seen as beneficial in the construction industry (Forbes et al., 2018). Especially through the Lean Construction Institute or the Associated General Contractors of America, educational games such as the Airplane Game, Marshmallow Tower (Rybkowski et al., 2016) or the Parade Game (Tommelein et al., 1999) are used to teach Lean principles. Lean training with educational games also exists from within the Lean Community or in university settings (Tsao et al., 2012). The focus of the educational games is on LC or methods which are used by IPD. Playful learning approaches that are explicitly used for teaching IPD principles were not found during the research. This represents a research gap that this paper attempts to fill.

DEVELOPMENT OF THE GAME

OVERVIEW

The previous section dealt with the didactics that must be taken into account when creating an educational game. The game is a simplified representation of reality. In this case, it is the project execution with the help of IPD. A simulation game reality must be derived from this reality. In this reality, the structure of the educational game has to be defined and at the end, a detailed elaboration has to be created. This procedure is shown in Figure 4. The development can be divided into three steps. Each of these steps has a methodical focus. For the first two steps, two workshops were held using the design thinking method. In this way, ideas for the development could be generated and elaborated. After the workshops, the findings had to be translated into concrete game material. No further support from experts was required for the development steps described here.

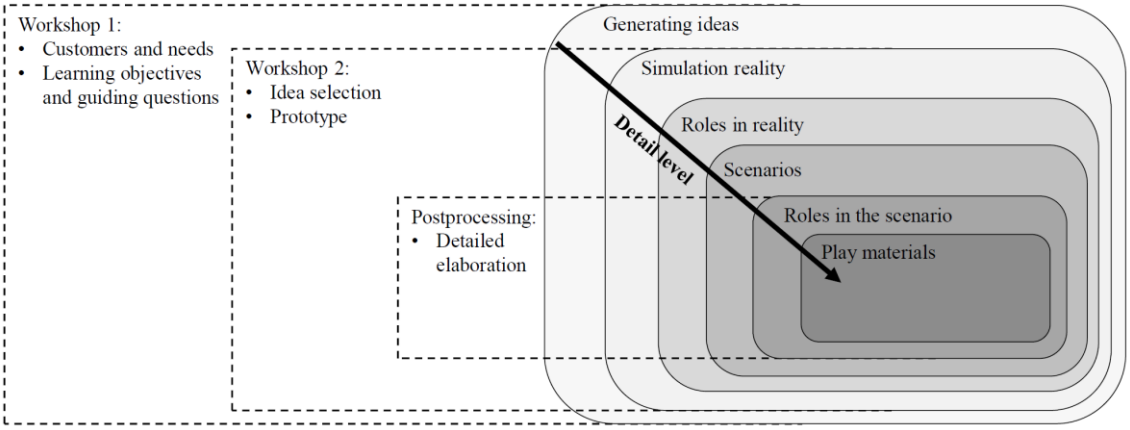

Figure 4: Approach to simulation game development

WORKSHOP 1

The overall goal of the first workshop was to generate ideas for the IPD educational game. The design thinking process was used in the workshop. The process can be divided into two sub-areas. The first is called the problem space, where primarily the challenge is investigated. It is specifically about understanding the problem, exploring it, and defining the core problem. The second area is the solution space. Here, creativity is a decisive factor. Ideas are generated, prototypes are developed and subsequently tested (Avenarius, 2012).

As shown in Figure 5, the overall objective for the first workshop is to capture the problem space, which is done in the first four steps, up to and including formulating guiding questions for the educational game. Furthermore, generating ideas is the first step in the solution space of the design thinking method.

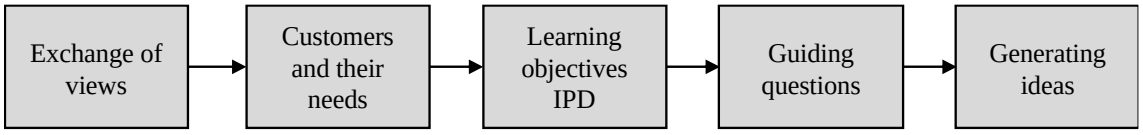

Figure 5: Procedure in the first workshop

Four experts with experience from IPD projects participated in the workshop. The workshop started with an exchange of views among the participants on the topic of the

IPD educational game. It became apparent that the workshop participants attach importance to the interaction of fellow players, the reference to practical examples of IPD and the use of an exciting implementation. A key statement from one participant is that an innovative project delivery model like IPD needs an innovative educational approach to teach its principles.

The next step was to identify potential customers of an educational game and their needs. It can be seen that the possible group of players for the educational game is large. For example, building owners, project controllers, planners, or contractors are represented. The fundamental needs of the users are to build trust in Integrated Project Delivery as well as the IPD team and to develop an understanding of IPD.

Based on the needs, the next step was to capture the learning objectives for an IPD educational game. Three learning objective clusters emerged. The cluster "IPD culture" includes learning objectives that are specifically intended to build trust. These include, for example, a "best for project" attitude, team building, and a collaborative attitude, among project participants. The cluster "multi-party contract" is a collection of learning objectives related to establishing an understanding of Integrated Project Delivery. These include, for example, the compensation model and decision and conflict management. The third cluster is the organization in IPD, for example focusing on the organizational structure.

In a further step, a guiding question for the IPD educational game was formulated for each cluster. The guiding questions are "How can the culture be actively experienced so that the participant builds trust?", "How can the functioning of the most important parts of the multi-party contract be experienced so that the participant understands it?" and "How can the processes and responsibilities in the different groups of the organizational structure be communicated so that the participants are aware of their task in the respective group?"

The guiding questions are a support for the subsequent idea brainstorming. The implementation of the educational game should answer the guiding questions. In addition to more detailed approaches for the educational game structure, such as the use of marble runs, the Froebel tower or Lego building blocks, three general approaches were identified:

- A learning simulation that teaches all IPD elements
- A modular structure of the game with individual teaching modules for elements of IPD
- The use of an adventure game as a teaching environment, such as an escape the room game, set up as a fixed or modular educational game

WORKSHOP 2

The results of the first workshop served as a basis for the second workshop, in which the design thinking process was continued. The aim of the second workshop was to select the general approach for the realization of the IPD educational game and to develop a prototype.

Two experts with experience from IPD projects and the application of simulations participated in the second workshop. In the beginning, the advantages and disadvantages of the solution approaches were discussed between the participants in the workshop.

The discussion on the choice of a fixed or modular setup is complex and a consensus is not available. One argument in favour of a fixed structure, for example, is that a standardized educational game consistently teaches participants the essential IPD

elements. A modular educational game can be tailored to the wishes of the customer as well as to intended learning goals and thus be adapted as a product to the user.

In the discussion, ideas were considered which contained elements from the three general approaches. The educational game should have a fixed standard structure and be supplemented by modular elements. In the educational game, a common goal should be focused on by the participants, like in an escape the room game. A limiting decision towards one of the three general approaches becomes unnecessary by combining elements of the different approaches. A specific educational game approach was sought that meets this requirement.

The live simulation game was identified in the discussion as a form of game-based teaching. After a joint discussion of the live simulation game concept, this teaching and learning form was determined for the further procedure in the development of an IPD educational game among the workshop participants, since the required characteristics can be realized with it.

In the next step, taking into account the guiding questions for the educational game collected from the previous workshop, the cultural, organizational, and comprehension learning objectives for the simulation game were formulated. In the following, the most important learning objectives that were jointly recorded and discussed in the workshop are listed:

- Cooperation: Fast and open communication of information that only individuals possess
- Cooperation: Solution-oriented instead of searching for the guilty → "No blame culture"
- Cooperation: Appreciation for the perspective of the other → Interdisciplinary work
- Cooperation: Even in IPD there are conflicts
- Transparency: This leads to trust and better solutions
- Reflection: Recognizing the need to work on team behavior
- Compensation model: How the joint incentive system works
- Entrepreneurial action: Making "best-for-project" decisions and deciding under uncertainty
- Product optimization: Within the framework of the Conditions of Satisfaction (CoS), optimizations are desired
- Interests: Conflicting interests of the client and the other partners, especially in the validation process
- Creative role of the Project Management Team (PMT): The PMT has to create the conditions for successful work

DRAFTING

After the second workshop, the results were transferred into a concrete live simulation game. An example project for the game was being sought. The construction of a "Tiny House" represents a normal building project, only on a smaller scale. Taking up and transferring conflict scenarios from reality into a Tiny House project within the live simulation game seems to be possible. The didactic reduction seems to make sense and the idea is pursued further.

One goal in the live simulation game is that the players are mentally immersed in the project and that IPD can be experienced. This is realized through visualizations of the construction project and an exciting game story. A three-dimensional Tiny House model is built as part of the simulation development. Figure 6 shows an example of the exterior view of the model. The further structure of the simulation is presented in the following section.

Figure 6: Tiny House Model

STRUCTURE AND COURSE OF THE GAME

The framework of the simulation is the project "Construction of a Tiny-House". The construction project is carried out using IPD. The participants in the simulation are part of the PMT of the project. There is one owner, one architect, one interior designer, one timber constructor, and one interior constructor. Figure 7 gives an overview of the game process.

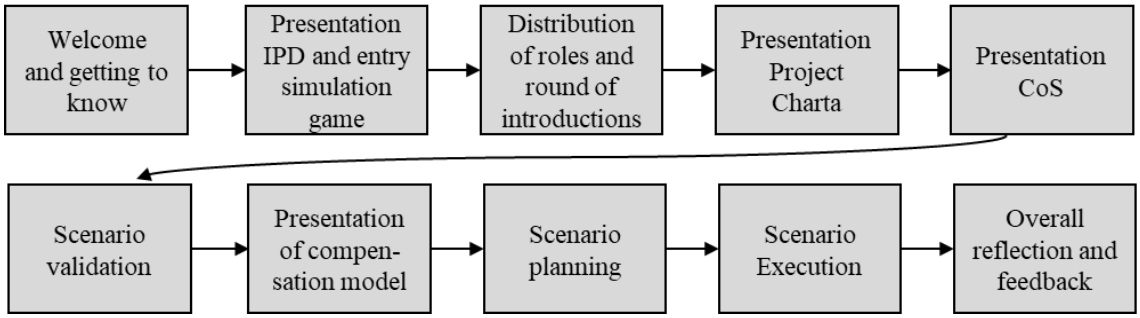

Figure 7: Simulation game process

With the PMT, the project is realized through the phases of validation, design, and execution. The simulation takes place in the "Big Room" of the Tiny House project. Materials exist for the visualizations in the simulation's seminar room to set up the Big Room. These include the Project Charter and the CoS for the project. Over the course of the project, additional visualizations and content are gradually presented in the Big Room. Five fixed roles exist in the project. Role cards for the five members of the PMT exist for the simulation. These cards contain general information about the person being played. Up to a number of participants of nine, all roles are doubled except for the owner of the building. From a number of ten participants, the simulation is implemented in duplicate.

There are then two teams that run the simulation in parallel. Two parallel visualizations of the course of the project are then displayed on two opposite walls. In addition, up to two observers can be used. The observers have the task of neutrally evaluating the course of the scenarios in the reflection rounds.

For example, a fictitious scenario is explained to the participants halfway through the validation. Individual roles are given additional information about the scenario that not

everyone has. The PMT, as the administrative lead in the project, is tasked with solving the problem. Scenario and role cards exist for the individual scenarios. Situations are formulated on the scenario cards that initially cause problems or further conflicts in the PMT and are to be solved together. Furthermore, there are scenario-specific role cards with individual information about the scenarios and general information cards, where, for example, the learning objectives and possible reflection questions of the scenarios are recorded.

Over the course of the simulation, participants are given information about the project so that they can become familiar with it. At certain points in the course of the project, the PMT is presented with challenging situations.

After the participants have solved the problem, or after a certain time, the scenario is ended and a reflection round is held. The participants can reflect together on what impressions they have just experienced.

Afterwards, the facilitator continues to explain the course of the project until the next challenging situation occurs, for example in design. At the end of the simulation, an overall reflection is conducted with the participants to reflect on their impressions and experiences.

Figure 8 shows an example scenario. This scenario deals with risk management in the design phase of IPD projects. The learning objectives addressed to the participants in this scenario are the compensation model, entrepreneurial action, product optimization and the creative role of the PMT.

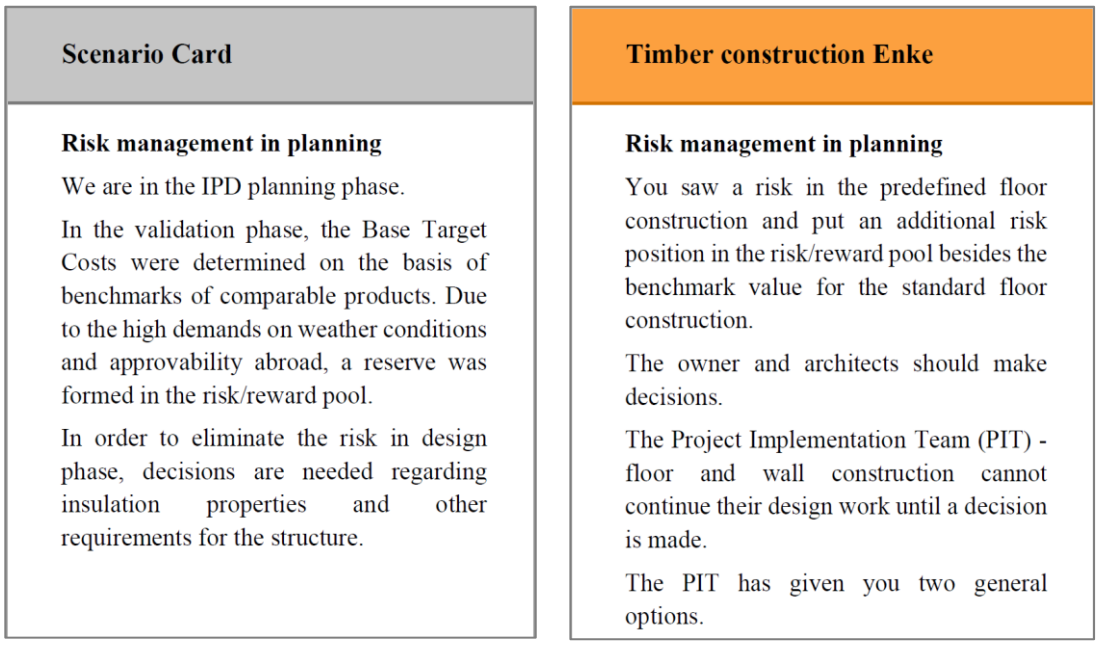

Figure 8: Example scenario in design

The IPD project and the process at PMT level provide the standardized setting for the educational game. The induced conflict situation forms the modular part and can be integrated into the game play depending on the learning objectives to be conveyed.

GAME TESTING AND FEEDBACK

The educational game has been conducted twice so far. Five people with experience from IPD projects participated in the first trial run. For example, the participants jointly

developed a project charter and discussed individual problems as PMT within the simulation (Figure 9). The participants were able to identify a learning effect and only made individual suggestions for adapting the scenarios and role cards. The structure of the educational game was perceived as very good.

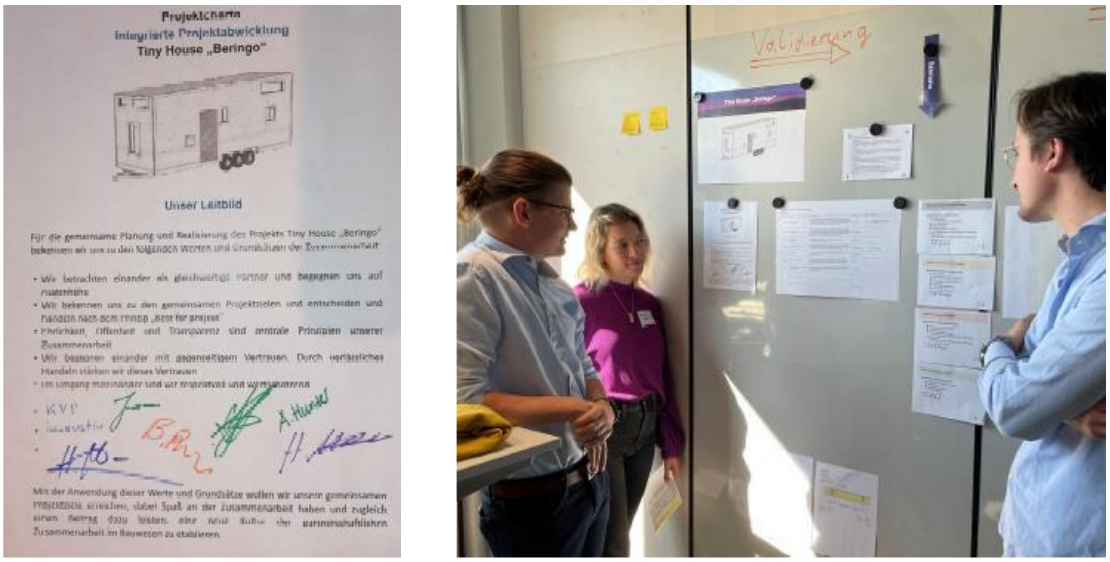

Figure 9: Game testing; Project Charter (left); discussion among participants (right)

The second simulation was carried out with people who had no previous experience with IPD. This showed a great learning effect. Based on the previous test runs, no further adjustments to the simulation are therefore necessary.

CONCLUSIONS

An innovative project delivery model like IPD needs an innovative educational approach to teach its principles. The innovative character of the developed IPD simulation game is shown by the combination of fixed and modular elements as well as fictional and reality-based components. Participants are supported by the moderation immersed in an IPD project wherein they are provided with a safe learning environment. They are given the opportunity to actively and independently from their actual company affiliation perform actions in the context of IPD without fear of consequences beyond the game. Over the course of the project, the change of mindset and processes associated with the use of IPD will be explained to the participants and visualized in a Big Room. Trial runs to date suggest that this goal can be achieved with the developed educational game.

The game is a snapshot. It needs to be continuously improved following the lean philosophy. For future developments, it would also be helpful to carry out basic research in advance on the legal and regulatory peculiarities of IPD in the respective country and the performance of IPD, so that an educational game can pick up on these. In addition, it would be useful to learn more about the functioning and interplay of IPD principles as part of further projects.

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