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Serious games in learning factories: perpetuating knowledge in learning loops by game-based learning

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Abstract

The usage of gamification in the contexts of commerce, consumption, innovation or eLearning in schools and universities has been extensively researched. However, the potentials of serious games to transfer and perpetuate knowledge and action patterns in learning factories have not been levered so far. The goal of this paper is to introduce a serious game as an instrument for knowledge transfer and perpetuation. Therefore, reqirements towards serious games in the context of learning factories are pointed out. As a result, that builds on these requirements, a serious learning game for the topic of Industry 4.0 is practically designed and evaluated.

Keywords: Game-Based learning; Gamification; Serious game; Learning factories;

1. Introduction

Building on the concept of gamification, that is to apply game mechanisms in non-gaming contexts such as teaching and learning [1], serious games are an innovative means of continuing education in general. Serious games prepare learning content in a playful way in education contexts. Therein, learning can be accompanied by an increased positive feeling and learners are addressed emotionally [2], which supports actively dealing with learning contents in order to make progress in the game and, within this, in learning. The learners are constantly motivated to continue playing in game-based learning by challenging game situations and are thus in a so-called flow state [3], in which they undergo

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learning loops without noticing. The use of game-typical elements in education and training can help to gain new and deepen existing knowledge in learning factories through its problem-solving and competitive character. The potentials of intended use of serious games to transfer and perpetuate knowledge in the context of continuing education, e.g. in the context of learning factories, have not been levered yet. Following a design science approach [4], in this paper a serious game for knowledge transfer and perpetuation is conceptualized on the basis of requirements as well as practically constructed and evaluated. By using gamification in learning factories, the existing process of training is augmented with either characteristics of games or the usage of games. Therein, game elements and game characters are used to repeat and consolidate knowledge and skills, and challenge the learners constantly. The goal is to show the advantage of serious games for knowledge transfer and complementary multipliers of learning for learning factories. Section 2 introduces the concepts of game-based learning, gamification, and serious gaming. The requirements of serious games as additional tools for learning factories will be derived in Section 3. Section 4 presents a self-developed serious game based on Industry 4.0 and related topics such as implications for work and new technologies. In Section 5, the game is evaluated regarding fulfillment of the requirements. Section 6 concludes the paper.

2. Theoretical backround

Learning in games positively effects learning success [5], working performance [6] and promotes the creativity of learners [7]. This so-called game-based learning increases motivation and fun within the learning processes by creating exiting and variable phases of tension and relaxation, which makes learning more interesting [8]. Depending on the game design, it has a positive influence on affective, cognitive, behavioral and sociocultural engagement of the learners [9]. From both a content and a motivational perspective, learning in games can therefore be helpful for learning in learning factories. A difficulty in designing playful learning settings consists of bringing the predefined learning objective into harmony with the feelings generated by the game [9]. Gamification of learning content offers a starting point for a game concept in which game-based learning can take place. The concept of gamification refers to the “use of game mechanics in non-gaming contexts” [10]. Examples for these mechanics are clear sequences, certain limits and clearly defined rules. Taken together, gamification refers to “the application of game mechanisms in non-gaming environments with the aim of enhancing the processes enacted and the experience of those involved” [11]. The context of learning within games, coupled with an intrinsic experience of motivation, can be described using the flow theory [3]. According to this, a feeling of joy and pleasure arises, which occurs in an intrinsically motivated activity when challenge and ability are balanced. The learner succeeds with seemingly no effort in the tasks s/he faces and enjoys the process. In the beginning, the abilities can be rather low, but they increase in course of the activity. However, as soon as an imbalance between requirements and abilities arises, stress, anxiety, boredom or disinterest may arise. The more a learner dives into the game environment, the higher the probability that the flow state remains. A flow state is recognized by focus, sense of control and loss of self-doubt of a learner [3]. Serious Games are played seriously or casually and have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement, which does not mean that serious games are not entertaining [12]. Especially today’s generation grew up adapting the increased flow of information by digital media and, thus, prefers games to conventional or serious work [13]. Eventually, for those new learners parallel processing and connected, interlinked learning processes are natural ways of gaining knowledge [14]. The effectiveness of gaming elements for learning in serious games, however, depends strongly on the individual dispositions of a learner. Observing gaming elements and pedagogical principles equally is necessary for learning success. On the contrary, overemphasizing gaming elements have negative effects like addiction. To raise the highlighted potentials, requirements for serious games as additional tools for learning factories must address game elements, game experience, and the factory specifics in a balanced way.

3. Requirements of a serious game concept for learning factories

On the basis of a morphology [15] that covers characteristics and features and a roadmap for digitizing learning factories [16], learning factory specifics are differentiated into the categories: objectives, setting, didactical concept, technologies and competences. The categories purpose, process, operating model, product are neglected for the sake of the serious game focus and replaced by the flow conditions and gamification requirements. As one example the *Research and Application Center Industrie 4.0* (RACI 4.0), addresses knowledge relevant for working in digitalized

production processes [17]. The learning *setting* is physical, and the *didactical concept* is a combination of problem and game-based learning. *Topics* addressed with the game are Industry 4.0, change of work, and digitization. The specific *competence* focus lies in the areas of interaction, process and organizational competence [17]. General *objectives* of the game are engouraging teamwork, conveying competences and thereby ensuring employees capacity to act in digitized working environments as well as sentizing for technology acceptance [cf. 5,9]. The implemenatation of gamification elements requires gameful elements, social interaction and providing a gaming experience to the learners [cf. 6,7]. The *flow conditions* presented above are also to be focused as a basis for a flow-based learning process through game design. Therefore, it is necessary to create an activating and interesting learning environment in which learners can learn and repeat content, based on clear targets and direct feedback as well as adjustable requirements. *General skills* address the abilities of taking self-determined decisions in new contexts, supporting transformation processes and the handling of real problems in authentic (learning) situations. These situations must be relevant for the learners and arouse their interest. Specific contents must also be placed in various problem contexts in order to enable learners to constantly re-contextualize knowledge. Table 1 summarizes the identified requirements for serious games in learning factories on the basis of the RACI4.0 use case.

Table 1. Serious game requirements.

Design requirements		*Competence and content requirements*	
Attributes	*Characteristics*	*Attributes*	*Characteristics*
Objectives	Encourage team work	General skills	Problem-solving capability
	Convey and deepen knowledge		Participation in transformation processes
	Ensure capacity to act		Independent decisions
	Technology acceptance		
Gamification	Playful elements	Competences	Interaction competence
	Social interaction		Process competence
	Gaming experience		Organization competence
Flow conditions	Clear targets	Factory specifics	Setting
	Direct feedback		Didactical concept
	Adjustable requirements and capabilities		Topics

4. A serious game on Industry 4.0

In the serious game, the players introduce Industry 4.0 technologies into a classic factory hall and, thereby, consider employees, processes, technologies, planning and application fields of Industry 4.0. They have to consider the benefits and risks of the technologies and principles. Complex relationships are presented in a simple and concrete form. A simple symbolism facilitates orientation. The game is a closed system with fixed rules and is played in three phases. In the briefing phase, the neutral game master explains the game and all the necessary key data. Also, learning objectives based on the specific factory topics (e.g tablets in production processes) are agreed on. This is followed by the game phase, in which the learners playfully modernize a factories workshop. The direct access to game elements integrates the players into the game in a highly immersive way. After the game master has ended the scenario or the fictitious production system has been successfully modernized, the game moves on to the debriefing phase, in which the learners reflect on their experiences by answering prepared questions that serve to evaluate the training programe and are in line with the previously defined learning objectives of the group. Both teams play on one board game.

At the beginning, the players are divided into two teams. Each team gets a team-token. A balanced level of knowledge prevents over- or under strain of knowledge in the teams (fit of challenges and skills). A way for archiving this is to randomise the players or to realise an allocation on the base of a self-assessment. The game master takes up a supportive role by guiding the process. Although the teams compete, the overall goal is to transform the production system into a smart and self-regulating system. Each team aims at achieving the highest possible number of innovation points in the transformation process. There are various fields of action for acquiring innovation points and expanding interaction-, process- and organization competences [17]. *Event fields* require the draw of an *event card* and the independent answering of the provided theoretical question or the handling of an action problem. *Community fields* require the draw of a *community card* and the answering of a more demanding knowledge question and the examination

of a use case. The cards are to be solved cooperatively within the team. On *malfunction fields*, the players must solve a production malfunction with the help of the entire group. Figure 1 (Fig.1) illustrates the fulfilled game.

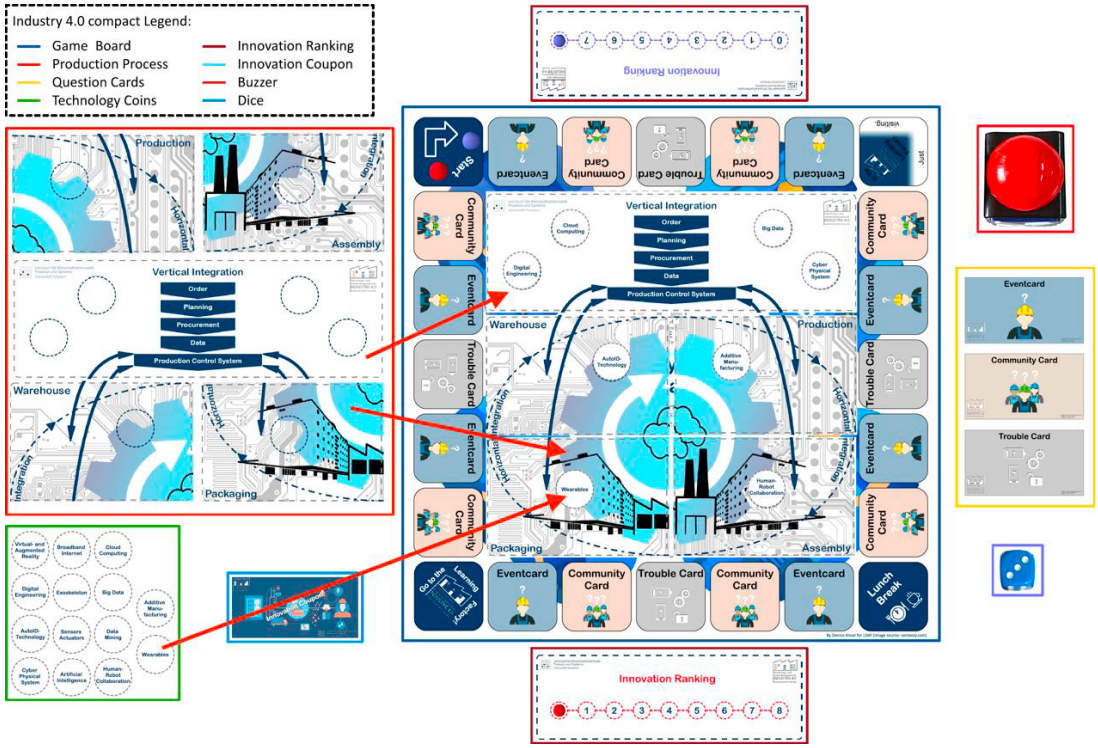

Fig. 1. Game elements.

The *Cards* address Industry 4.0-topics such as new technologies (implementation, control and networking), necessary skills and action problems in the planning, implementation and monitoring of new processes and structures. Taken together, this promotes interaction, process and organizational competence. Content provided in the game must be matched to the knowledge content that is conveyed in the learning factory. Thereby knowledge is deepened and expanded through additional learning loops. In the RACI4.0, participants learn, for example, the basics of digitized production processes (e.g. new technologies) in one-day training courses. These courses alternate between a phase for theoretical input, followed by knowledge re-contextualization in learning scenarios [17]. In the serious game which is applied after the theoretical input and practical sessions, therein gained knowledge is re-contextualized and consolidated. Thus, the knowledge questions provided by the cards are aligned with the contents of the other phasesin order to enable the learners to continue learning loops on specific topics. As a result, the serious game and especially the debriefing phase are complementary multipliers of learning processes and knowledge content by enriching theoretical and practical learning factory experience with game experience. Figure 2 (Fig. 2) illustrate the process.

A team receives an investment voucher for the correct solution of an event or community card. For a fixed number of *investment vouchers*, technical investments for production can be purchased. A successful investment leads to one innovation point. The *purchase request* is made by an investment buzzer. Purchases are to be justified argumentatively by the team and evaluated by the rival team. The subsequent discussion must be constructive with the group members simultaneously communicating and getting involved. Based on the team arguments, the game master ultimately decides on the successfulness of the investment. These game elements increase the degree of interaction between the players. If an innovation proposal is rejected, the team-token must be placed in the field “In the learning factory”. This also happens, if the teams are unable to solve a *fault field* or if a team accidentally enters the field “*Go to the learning factory*”. In the next turn, a team member has to draw an *event card*, which contains, e.g., questions regarding

employees, processes, technologies, planning, application fields of Industry 4.0 or specific measures to be applied for solving a specified challenge. If s/he does not succeed the task, the team has to draw a community card. If they do not succeed either, the team loses an innovation point. The team with the most innovation points wins. In the event of a tie, the number of innovation vouchers is decisive. Both the individual game elements and the competitive character are intended to provide the participants with an intrinsic motivational experience and a constantly high level of fun.

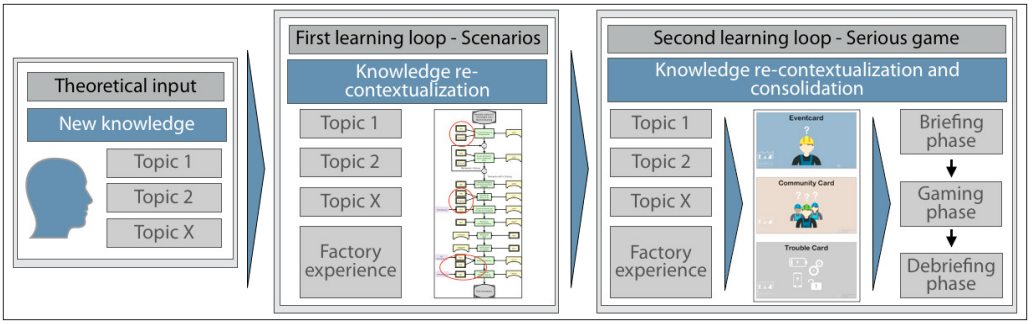

Fig. 2. Loop-based learning with scenarios and serious games.

5. Evaluation

During one-day training courses on Industry 4.0 and change of work, the serious game was applied as second learning loop with twelve test persons. With the aid of a closed ended-questionnaire (yes/maybe/no) addressing gaming and flow experience and competence development, a subjective assessment of the extent to which the requirements of the serious game have been fulfilled. Thereby, ○ represents a none fulfillment (< 25% yes), ◐ a partial fulfillment (25% - 75% yes), and ● a complete fulfillment (>75% yes) of the requirements by the game. The game is rather less effective in securing the ability of employees to act in the production environment. Instead, the simulation intends to prepare for future developments in Industry 4.0 and raises awareness of new technologies and their application cases. The aim of the serious game was to address the increasingly important interaction-, process- and organization competence in the context of digitized production processes. By promoting teamwork through cooperation and collaboration, this was achieved in interaction competence. As already indicated, this was only partially successful for organizational and process competence due to the lack of practical experience (Tab. 2). However, this problem can easily be remedied by the underlying modular and expandable game principle. In the course of the workshop it became apparent that the degree of difficulty of the question cards could be too easy in some cases and that the participants might therefore be underchallenged. This must be investigated in further practical use. A solution could be to prepare decks of question cards for different knowledge levels (e.g. *students* and *workers*). Generally, the participants were able to follow the course and the objective of the game without any problems. Answering the question cards caused hardly any problems, and the relationship between questions to be answered independently and cooperatively also turned out to be suitable. The playful learning and checking of existing knowledge was fun and aroused curiosity.

Table 2. Evaluation of the requirements.

Design requirements			*Competence and content requirements*		
Attributes	*Characteristics*		*Attributes*	*Characteristics*	
Objectives	Encourage team work	●	General skills	Problem-solving competence	●
	Convey and deepen knowledge	●		Participation in transformation processes	●
	Ensure capacity to act	◑		Independent decisions	●
	Technology acceptance	●			
Gamification	Playful elements	●	Competences	Interaction competence	●
	Social interaction	●		Process competence	◑
	Gaming experience	●		Organization competence	◑
Flow conditions	Clear targets	●	RACI4.0 content	Strategic production design	●
	Direct feedback	●		Digitized production processes	●
	Adjustable requirements and capabilities	●		Industry 4.0 technologies	●
				Digitized supported maintenance	◑

The evaluation shows that a large part of the requirements are fulfilled in the realization of the serious game concept. It offers a framework that explains which changes, triggered by digitization, production employees will encounter in future. The game scenario consists of the participants working cooperatively and collaboratively on an overall result, while at the same time holding a cross-team competition. Through playful elements and social interaction, the fun of the game can be increased and motivation for learning achieved. The participants should be encouraged to make their own decisions and to participate in transformation processes. Knowledge acquired through learning scenarios can be deepened and consolidated. The objective realization was only partially successful due to the game element of the cards, in particular the fault cards, in which certain real-world action problems have to be solved. However, through further development of the game content, organizational and process competencees could also be better addressed. This is made possible by the modular and expandable game structure. The game supports an intuitive use, both for the learner and the coach. In addition, there is adequate flexibility in the duration of the game. It is a closed and complete serious game concept ready for use in the context of a learning factorie. As part of the factory teaching concept (e.g. one-day training courses), it helps to gain new knowledge and deepen the knowledge from the learning factory.

6. Conclusion

The aim of the research presented in this paper was first to highlight serious games as additional tools for learning factories and second to design and implement a practical prototype which helps learners to perpetuate knowledge gained in a learning factory. A learning process based on learning loops can be initiated and is particularly conducive to efficient knowledge transfer. In addition to factors such as motivation and enjoyment, participants achieve a positive learning effect as long as challenge and skill are balanced. Since the concept of the game scenario emphasized a high degree of social interaction between the players, the choice fell on a classic serious game form with an orientation to the concepts of simulation and business games. The serious game concept can be adapted and extended to the needs of an advanced training seminar due to its modularity and extensibility of its content. Taken together, serious games have a high potential to support vocational training in learning factories as additional teaching instruments and, thus, increase both fun and efficiency in learning.

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