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Employee qualification by digital learning games

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Abstract

Global competition and individual customer requirements generate challenges for manufacturing companies. To cope with these challenges, companies require an increased level of flexibility. In the first place, this flexibility has to be provided by the employees, as they are one of the key success factors for mastering change. An essential prerequisite for this is a high level of employee qualification across all areas of the company.

The learning factories approach has garnered particular attention in recent years as a playful and efficient way of learning the principles and methods of processes improvement. The drawbacks of this method include the limited, non-holistic perspective of each trainee as well as the non-recurring knowledge transfer. Moreover, this kind of qualification requires the trainees to be in the same place at the same time.

These downsides can be successfully countered by supplementing learning factories with a digital learning component depicting the learning environment, as digital learning will enable individual learning routes for all trainees and is accessible at all times and all places.

This paper serves to outline the idea of serious learning by using digital learning games along with the attendant benefits. Over and beyond this, it also presents a digital learning game for teaching specific lean production methods.

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Keywords: Learning Factory, Digital Learning Games, Lean Production, Line Balancing

1. Introduction

Growing globalization and the attendant global competition are causing an ever more intensive market and technology dynamic where manufacturing companies are faced with new challenges in ever-shorter cycles [1]. If they

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want to keep up with this dynamic, companies need to respond to variable customer requirements flexibly and efficiently. A greater variant flexibility and production in ever-lower batch sizes down to merely one are examples of the challenges that the companies' production structures and organizations need to be adapted to. However, adaptations such as these also call for employees who are suitably qualified and versatile for the transformation of production processes. This accords a key role to the in-service personnel development, and hence the continuous further training of employees on all the organizational levels of a company [1]. The conventional methods of providing employees with in-service training are meanwhile limited in their efficiency and achievable learning success, so that the need for new teaching and learning methods is great [2]. This paper will place a particular focus on the qualification of direct employees with regard to the lean production philosophy.

2. Options for the continuous and further training of employees

There is great variety of proposals for the further training of employees. They largely differ in the design of their contents and methods. While the content is mostly oriented towards the intended objective of the in-service training, the methodical approach is defined by the quiddity of the teaching concept and based on an underlying theory of learning [3].

2.1. Categorization of teaching concepts

The aim of the teaching concept is to initiate and support the learning itself, as well as to secure the learning results [4]. According to MYRACH and MONTANDON, teaching concepts are categorized by the way of the learner's commitment to a time and place. Therefore, a differentiation is made between classroom teaching and distance learning in the in-service training (Figure 1) [5].

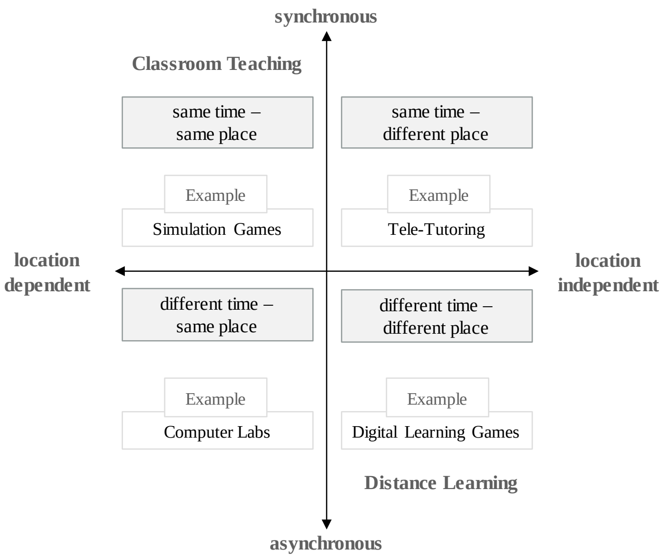

Figure 1: Categorization of teaching concepts [5], [6]

As subcategories of the teaching concepts, classroom teaching and distance learning are both subject to typical restrictions that can have a negative impact on the learning success. An overview of the strength and weaknesses of these concepts is provided in Figure 2.

	Classroom Teaching	Distance Learning
Advantages +	• Taught subjects can be embedded in a practical application context • Interaction with other trainees develops additional skills • etc.	• Possibility of time- and location-independent learning • Greater liberty for trainees in designing their individual learning process • etc.
Disadvantages -	• Commitment to a specific time and place • Only limited design options for individual learning processes • etc.	• Hardly any development of social skills for lack of interaction with other trainees • Digital mediation complicates the knowledge transfer to practical application • etc.

Figure 2: Benefits and drawbacks of classroom teaching and distance learning [5], [6], [7]

What is emerging is that the use of classroom methods is essentially recommended in the context of a practical application, which means to be able to act in a haptic and close to real-world environment [7]. Whereas distance learning methods are particularly suitable where the learning is meant to be location-independent, for example because of organizational efforts, or where an individualization of the learning process is to be enabled [6].

The training offerings for employee qualification in the area of lean production are also manifold. Given their focus on a practical application context, most of these proposals are based on a classroom principle, however. At these events, the trainees are familiarized with the subject area by means of lectures or case studies. So-called learning factories are also increasingly gaining importance in this context for a number of years.

2.2. Teaching concept: Learning factory

The use of learning factories presents an efficient method for transferring practical method knowledge, particularly in a lean production context. Besides the study by CACHAY ET AL. [8], the great number of learning factories that have sprung up throughout Europe in recent years also confirms the success of this type of learning.

The learning factory concept is based on an action-oriented approach of teaching and learning. It combines traditional theoretical sessions with practical, informal learning experiences. This is meant to provide for a deeper anchoring of the transferred knowledge, thus boosting the learning effect and the skill of applying this knowledge in real application cases. The combination of theoretical learning units with practical application scenarios is important in the process to create a direct connection between recent learnings and their application [9], [10].

Despite the mentioned advantages, learning factories also suffer from the typical weaknesses associated with classroom teaching. They are tied to a specific location, do not permit a full individualization of the learning process, and the "experience" is often role-specific, so that there is no comprehensive overview of the game situation.

Given these restrictions and/or drawbacks, ABELE ET AL. and others continue to perceive a need to innovate this learning method, for example by supporting it with media contents or distance trainings [2].

One possible learning method that meets these demands and can be regarded as a complement for classic learning factories are digital learning games based on the idea of serious gaming. They resemble learning factories because of their ludic reproduction of real situations, but differ from them where the commitment to a specific place and time is concerned.

2.3. Serious Gaming and digital simulation games

The term 'serious games' was first used in 1970 by CLARK C. ABT. He defines serious games as "games[, that] have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.

This does not mean that serious games are not, or should not be, entertaining“ [11]. BREUER in turn understands the term serious games as denoting "all forms of digital game […] whose purpose extends beyond mere entertainment" [12].

Another term often heard in this context is the so-called digital game-based learning (DGBL). This means "any marriage of educational content and computer games" [13]. Considering the great similarity between the respective definitions, these terms shall be understood as synonymous and summarized under the umbrella term of 'digital learning games' below.

Digital learning games can generally be characterized by six features: interactivity, multimediality, involvement, challenge, social experience and reward. These features and the options available for shaping them enable learning results that are not achievable with other media at all or only to a very limited extent [12].

The interactivity between the players and the digital world of the game, for example, allows for a new combination of learning with direct experience [14], while also enabling an experience of multi-sensory, "embodied learning" [12]. In addition to this, the player is also provided with direct feedback for his or her accomplishments by way of the input-output loops [13]. This differs from classical learning in that learning from mistakes and trying again in a trial and error approach is an integral and natural part of the game [13]. Any mistakes made are meanwhile not meant to be punished, but merely pointed out [14].

The multimediality enables a great range of different learning contents and modes, which can be presented in a very complex manner to boot. A player can experience historical backgrounds in a true-to-detail historic scenario that is underpinned and supplemented by texts, for example [12].

To ensure the user's motivation with the help of the game, the person needs to be involved in it. This enables learners to completely immerse themselves in the world of the game, which helps to keep them interested, and thus sustain their motivation to continue playing and/or learning, while reducing the risk of distractions at the same time (involvement).

The features of challenge and reward encompass the possibilities of adapting the difficulty of a task to a user's capabilities, thus boosting the intrinsic motivation while simultaneously preventing the game from becoming too easy or too challenging, and of providing a certain reward for achievements, for example by reaching high scores or new levels. This heightens the motivation effect [12] and continuously eggs the player/learner on to continue learning, not to give up, and to take on new challenges [15].

The social experience finally enables shared learning, mutual assistance between players, and networked learning [13].

These characteristics also set DGBL and serious games apart from related digital teaching methods such as e-learning or edutainment.

To what extent the learning method of digital simulation games brings about an increased efficiency of learning effects has not been clearly established yet. The reason for this is the multifarious forms and realization options, hardly comparable with one another comprehensively these days [16]. However, that a positive effect is possible has been confirmed by many publications that have been able to demonstrate the beneficial impact of serious games (e.g. [17], [18], [19], [20]) or gamification approaches (e.g. [21], [22], [23]) on learning results.

But if the benefit of these digital learning games is to be maximized, it is recommended to not understand and use them as an isolated teaching activity, but to rather integrate them in a comprehensive teaching concept instead [24].

3. Combination of real and virtual simulation game environments

Following the recommendation of an integrated provision of digital and real teaching concepts, what suggests itself is to link the method of the learning factory with the concept of digital simulation games. It is furthermore meaningful for ensuring a continuous learning experience to also use the real environment of the learning factory as a basis for the digital simulation game and create a digital representation of it.

Combining the learning factory with its digital version concatenates the benefits of classroom teaching and distance learning, leading to a better and most of all more sustained qualification of employees. This combination of traditional classroom teaching and virtual distance learning is referred to as blended learning [5].

The advantages of integrating a digital simulation game can be grouped into those arising from the interaction with the real simulation game and those resulting from an autonomous application that is divorced from the real game in time. The use of virtual environments in the training offers particular advantages because proposed solutions can be tried without risk. This can help to reduce the number of "trials" in the real rounds of the game, and to arrive at a better solution overall. In addition, it will also provide for a better understanding of causal relationships, which boosts the learning effect. As an independent application, the digital learning game meanwhile not only allows for time- and location-independent learning, but can also cater to individual knowledge levels and needs. A summary of the benefits is presented in Figure 3 [6].

		Benefits of combining real and virtual learning environments for …	
		… players	… companies
Benefits	In the real simulation game	• Experiential learning through direct implementation in the learning factory • Trying out of solution ideas without risk • Improvement of the solution quality • Broader understanding of the problems amongst all players of the simulation game	• Time- and location-independent learning leads to lower training costs • Higher training quality, particularly where the retention in memory is concerned If company-specific, virtual simulation game environments are used: • Greater transfer thanks to the closeness to own practices • etc.
	In independent application	• Intrinsic motivation to find a solution thanks to ludic character • Time- and location-independent learning • Customization to individual requirements and knowledge levels in independent problem-solving	

Figure 3: Advantages from linking real and virtual learning environments (based on [6])

The challenge in linking both teaching concepts, and particularly in the design of digital simulation games, resides in porting the desired teaching contents and learning targets in a manner ensuring their optimal achievability/accessibility for every learner/player despite their flexible, customized learning structures [12]. Another risk that has to be addressed is the fact, that learners might be overwhelmed by the diversity and scope of the learning material [5].

How an integration of real and digital world could look like will be outlined below using an example from the IFA learning factory.

4. Digital learning game about line balancing using the IFA learning factory as an example

The IFA learning factory is a modern learning environment where the essential operational workflows of manufacturing companies can be mapped. A particular focus besides the knowledge transfer in the fields of workplace design, production controlling and factory planning is on lean production. The corresponding training is aimed at introducing the trainees to the principles of lean production in a playful manner while highlighting the ways and means by which a production system can be leaned down.

The game embraces all the company departments involved in the order handling such as the assembly, storage / disposition, in-house transport, accounting and production controlling. External parties such as suppliers and customers are also represented in addition to this.

12-15 trainees can take part in the training altogether. In the simulation game, every trainee in turn slips into one of the mentioned roles and retains it for the entire duration of the training. Role changes are not envisaged.

Product

The product to be manufactured is a helicopter made from 18 components. The helicopter itself comes in four different versions. A distinction is made here between two volume products and two exotic variants.

Production structure

The helicopter is manufactured at six manual assembly stations that are interlinked flexibly. The arrangement of the workplaces is specified at the beginning of the training and can be changed by the trainees during the following practical rounds. The manufacturing in the first round is based on the push principle, with a batch size to be specified by production control. The corresponding batch is then conveyed from one workstation to the next with the help of transport containers.

At the start of the game round, the trainees are briefed in their roles. The assembly workers are provided with digital work schedules embracing the assembly processes and their sequence. The required materials are centrally provided by the warehouse. There is no direct provision of materials except for bulk goods.

During the game rounds, the trainees have to face a great number of problems that they are going to solve by the application of lean production methods.

One important objective besides reducing the batch size resides in balancing the individual work contents of the workplaces to fight the waste caused of imbalanced workloads. During the training, the assembly workers form a team for this issue and for tackling this task. Based on the experience gained in the game rounds, the trainees meanwhile discuss what a redistribution of the work contents could look like, and which measures would need to be applied for it. The downside of this is that their understanding of both the problem and the solution is only provided within this team. Trainees with roles outside the assembly department will neither be able to recognize the problems created by imbalances and the attendant bottlenecks in the system, nor will they immediately recognize the benefits of the line balancing method. What has been moreover emerging in reality is that the groups often suffer from an uneven distribution of knowledge. There are always trainees who are more knowledgeable, for example. Those trainees clearly advance and accelerate the solution process. One possible result of this is that not all of them may be able to comprehend the approach.

The introduction of the digital learning game is designed to serve three aims overall:

1. Use of the game to support problem-solving (in parallel to classroom training)
2. Outlining the problems caused by imbalanced process cycles and highlighting the potentials of reducing these time fluctuations for all trainees in the learning factory (in parallel to classroom training)
3. Use of the game for independent problem-solving and for consolidating the knowledge after a classroom training (distance learning)

In the course of the digital simulation game, the trainees can freely decide about the distribution of the work contents to the stations. This merely requires an allocation of the assembly component to one of the workplaces. In addition, the trainees are able to change the number of workstations simultaneously. A summary of the station times resulting from the distribution is shown at the bottom of the screen for controlling purposes (see Figure 4).

Various information has been filed underneath the user-friendly interface, including a comparison of every decision with the underlying assembly sequence of the helicopter, for example. If the trainee tries to distribute the work contents in a manner that is not possible in terms of the helicopters construction, this will be identified as a non valid option. The cycle times of the individual work activities have been identified in the real learning factory by means of an MTM analysis. They therefore correspond to the approximate time required in reality.

This information enables the players to balance the line. The efficiency of the applied measures can be checked by the simulation of an experimental game round afterwards.

To further boost the learning experience and approximation of reality, the real production data are meant to be transferred to the digital learning game in a next step. This will for example enable any direct rearrangement of work contents in the learning factory to be mapped in its digital mirror image, which would particularly improve the use of the digital game as a planning tool in the improvement stages of the classroom training.

Figure 4: Virtual simulation game dealing with the method of line balancing

How an interplay between the two methods of the learning factory (classroom training) and the digital learning game based on serious learning principles (distance learning) can work out will even emerge without this expansion, however. One essential benefit from the integration of a time- and space-independent component is the possibility for trainees to try out various solutions and repeat the solution process as often as they like. This ensures a sustainable consolidation of the learnings. However, an independent use of the digital simulation game would also be a conceivable variant. This would call for a number of expansions, however. That is why further modules for the areas of one-piece-flow, drum-buffer-rope/theory of constraints, material kanban and milk run have already been developed and integrated in the digital learning game used at IFA.

5. From the individual application to an independent digital learning game

The application of digital games shows that they can do more than merely support and complement the real solution process. Instead, they also can be used as the sole method of employee qualification. The benefits would not only include the possibility of making the game accessible to a broad group of users, but also that this could be done with little effort, given the independence from a specific time and place.

The digital learning game about line balancing developed at IFA could principally also serve as an independent module for transferring knowledge in companies. However, looking at the features which distinguish digital learning games and whose respective fulfilment levels has a corresponding impact on the attendant learning success, one can see that their stand-alone application suffers from a number of deficits (see Figure 5).

While interactivity and multimediality are largely provided in the game already, the areas of player involvement and motivation (challenge and reward), especially, show that the presented line balancing example could still be further optimized. This should be aimed at increasing the ludic character and at boosting the motivation by posing problems that are more complex.

In this context, it seems to be expedient to create an environment that is distinguished by a great number of challenges, which in turn need to be overcome by the application of various methods. The mutual interlinking of methods and attendant highlighting of the interactions between their respective impacts lead to a certain "complexity" whose resolution represents a corresponding motivation for trainees.

If this is successful, the digital game represents an elementary element for better and more sustainable knowledge transfer.

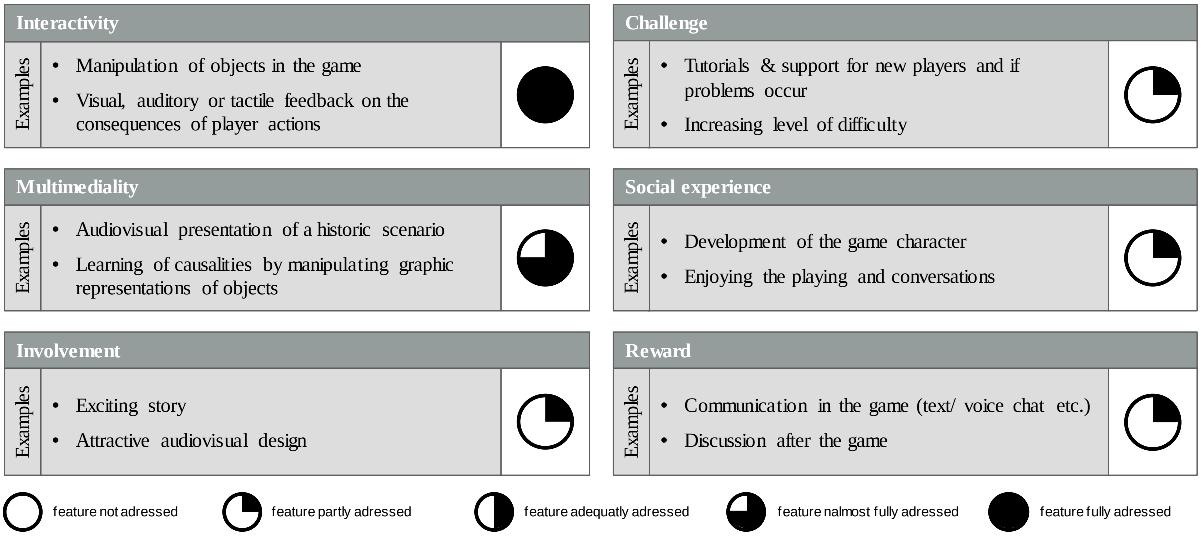

Figure 5: Digital game features and their fulfilment levels in the developed learning game

6. Summary

An expansion of the IFA learning factory with the digital planning game has the potential to lead to a better knowledge transfer during as well as after the training. Especially the possibility of reproducing solution approaches independently from spatial and temporal framework conditions is a unique characteristic of digital learning games in this regard. The planned digital mapping of all training contents of the real learning factory will also permit the game to be used as an autonomous in-service training proposal. If the additional integration of framework conditions from the practical experience of the users and/or players in the game is successful (e.g. by suitable interfaces with the MES), the learning effect will be increased even further because of the easier knowledge transfer into their own practice. The positive effects of digital learning itself but also in combination with the learning factory will be examined further in the future.

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