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# A survey of gamified Augmented Reality systems for procedural tasks in industrial settings

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**Abstract:** Gamification is the adoption of game design elements and mechanisms into non-game contexts. As gamification has been a growing approach to increase people's performance in multiple disciplines such as education, service and marketing, it is necessary to question if gamification is also applicable in the industrial setting. In this paper, we discuss the specific requirements of a gamifed Augmented Reality system in an industrial production setting, its applications as well as challenges.

*Keywords:* Gamification, Augmented Reality, Industrial Production, Gamified Training

## 1. INTRODUCTION

Gamification is one among many concepts that built upon the prospect of utilizing the potential of games in other application domains. This same foundation also nurtures several other concepts namely "serious game" (Ritterfeld et al. (2009)), "alternate reality games" (McGonigal (2011)) or "games with a purpose" (von Ahn (2006)). That is why gamification is so often being mistaken with those.mGamification is a fundamentally new term. While documentation showed the first use back to 2002 (Pelling (2011); Engineering (2019)), there were no academic definitions available until 2011; when Sebastian Deterding marked out "Gamification is the use of game design elements in non-game contexts" (Deterding et al. (2011)). This is the most reliable definition and widely used by academia. Knowing that the idea behind gamification is to embolden motivation and user engagement, it typically produces the desired result by targeting people instinct of mastery, autonomy, and competition. However, it would be a mistake to assume that making use of any random game mechanism would easily achieve these goals.

Gamification has been embraced by many domains and particularly considered as a potential "disruptive innovation", which was foreseen to replace the existing practices, in education (Christensen and Raynor (2003)). There are a lot of successful stories of gamification application to prove its benefits, from e-learning to exercise, from team cooperation to the service industry (Chou (2019)). In the context of production environment, gamification is expected to play an important role in increasing staff satisfaction as well as optimizing the efficiency of a process as in those mentioned areas. This is especially advantageous in the modern industrial setting, which is highly complex and intensively requires human-machine interaction. Unfortunately, gamified applications in the production area, precisely human assembly work, are clearly missing.

Moreover, industrial training in the present-day witnesses the use of new emerging technologies, including Augmented Reality (AR). Maintenance and assembly training and support have always been one among the key application fields of AR (Lamberti et al. (2014)). AR allows users to interact with the virtual objects which are superimposed upon the physical world in a real-time manner. AR applications provide different levels of in situ guidance for end users either as on-site support or remote experts.

In this paper, we are going to address the question if gamification in combination with AR for industrial training can offer potential for increasing user performance and experience. First, we will discuss what are the contexts and requirements that need to be taken into consideration. Then, we will review several applications with scientific evidence to understand gamification effectiveness. It is followed by a discussion of obstacles and challenges.

## 2. REQUIREMENTS

In contrast to the mentioned sectors, gamification in the processes of industrial production maintains quite an unknown territory. A meta-analysis from Seaborn et al. showed that gamification, in general, is notoriously challenging due to its highly context-specific character (Seaborn and Fels (2015)). This means the situations in which gamification is adopted may appear trivial at first could return a surprising result. Adding a similar gamified design into different circumstances does not always yield similar outcomes. Therefore, it is essential to highlight the specific requirements of the production context.

First, keeping the user default focus on the procedural task. The nature of assembly work is that it is highly structured (Niesenhaus (2013)). The procedural training demands the user to learn how to perform a specific task and acquire the knowledge related to methods, procedures or operation of equipment at the same time. It is the

worker's duty to continuously maintain a complex cognitive association through the whole process. The three main things that demand attention are necessary tools, assembled parts, and the work sequences. They are the default focus of the user. Korn et al. (2015) argued that gamification in production must support only implicit interaction and avoid any kind of explicit interaction. Understandably, the distraction in production work can result in damaging the products, the machines and the user himself. However, in the context of AR training, the danger could be minimized or even eliminated. As the user learns via interacting with virtual tools and components, mistakes are allowed without a real injury. However, a good gamification designer should take into account the level of how much virtual objects are available to the users, how to simulate a sense of consequences and not to constantly taking the user focus away from the main task.

Second, gamification should support low cognitive workload. As in Korn et al. (2015), the authors identified displaying the gamification design in close to use locus of control as a separate requirement. However, we suggest considering it only as an aspect of supporting low cognitive workload. Any "in situ" display would reduce potential distractions and minimize mental workload from switching attention (Shneiderman et al. (2016)).

## 3. APPLICATIONS

Research on the gamification application for industrial use cases is still a greenfield. However, many researchers in both manufacturing industries and academics have shown their interest in exploring the potential of it. In this section, we are going to review only gamification applications that are relevant to the requirements in section 2.

### *3.1 Assistive (or Assisting) System*

In the work called the Industrial playground, a purely functional assist system for an assembly task was replaced with a new gamified design (Korn (2012)). The idea was resembling working sequences as the classic puzzle game Tetris. The procedural process was fixed and predetermined where each step was visualized as a brick. Color changing from green to red, along with audio feedback allows users to directly see their performance. The author used the technique called "shadowing", where user competes to their own record. This record is continuously updated daily and weekly derived from the user's performance so that the level of challenge is corresponding to the individual's capacity. In recent works, Korn's research group continues proposing several different gamified designs as well as exploring multiple aspects of their effectiveness. A similar approach to making use of color to indicate user-specific time progression was used. Two different designs, "Circles & Bars" and "Pyramid", were proposed (Korn et al. (2015)). In the "Circles & Bars" design, each work step is displayed as dice with a number corresponding to its sequential position. A single color, whose radius reduces whenever the color changes, encircles the dice. When a work step is done, the remaining area of the circle is added to the bar. This bar functions like a point system where it is filled up by achievement and left

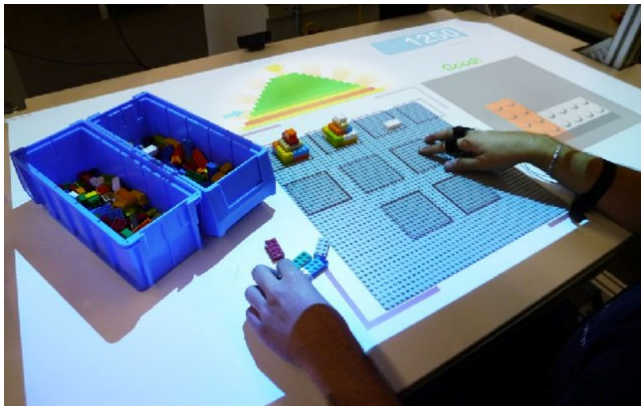

Fig. 1. Gamified design of feedback and instructions are projected into the work space (Korn and Rees (2019)).

empty when a mistake is made. In the "Pyramid" version, each work step equivalents to a step of the pyramid. A virtual figure of the user will climb up the pyramid as the user proceeds. It is the step of the pyramid where the figure stands on changes the color. The figure will receive the cup at the top of the pyramid when the whole process is successfully performed, otherwise, the pyramid displays red.

Both designs later were tested in a controlled experiment. They were projected into users' working space as an assistive application for impaired individuals. It was an optimistic result when users were open to the use of gamified systems. Between the two proposed approaches, the "Pyramid" was favorable. Yet it was a choice in a selected collection. Fig. 1 illustrated an updated version of this design in combination with scores, progress and time feedback (Korn and Rees (2019)).

A further example is the training application for changing a robot arm battery (Nguyen and Meixner (2019)). This is one among very few studies where gamification is combined with emerging technology, Augmented Reality, for assembly training. The system offers step-by-step training using a Mixed Reality headset, Microsoft HoloLens. A sense of achievement is visualization via a point system and progress bar (Fig. 2 ). This is a dual feedback system with optical and auditory cues. As to create a sense of autonomy/mastery where the user feels in control of the situation, signposting will indicate the next component to which the user has to interact. This eliminates the frustration for users, especially novices who are normally the target group of training.

### *3.2 Training System*

A controlled experiment was conducted with two groups, one exposed to the gamified design while the other performed the identical process without the gamification. While the result also indicates a favorable trend to the gamified design, there was no statistically significant difference between those.

Achim Kampker introduced another gamified application called "Sequence Poker" in the automotive industry (Kampker et al. (2014)). The aim was to improve learning efficiency in production ramp-up. The training was designed as a board game (Fig. 3 ). On the play board, all

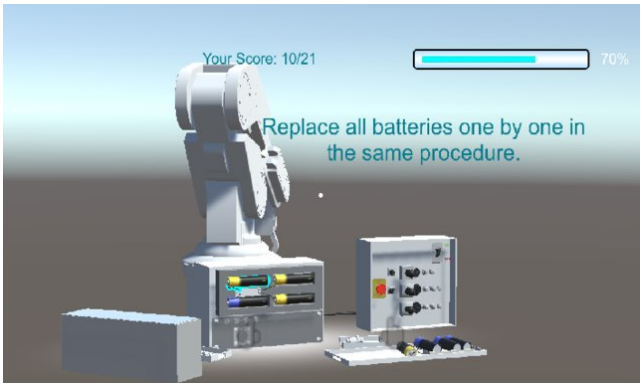


Fig. 2. Gamified training for changing robot arm battery with points, progress bar and signposting (Nguyen and Meixner (2019)).

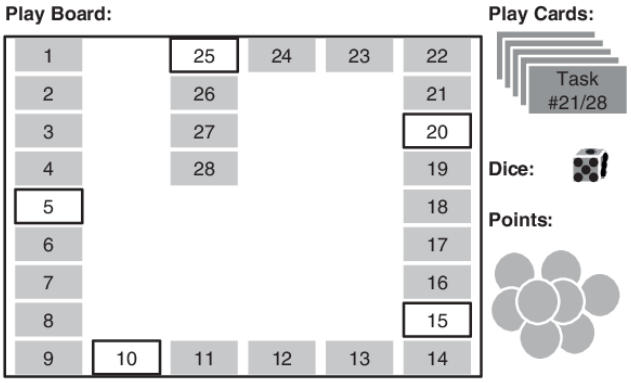


Fig. 3. Learning assembly task sequence through simulating rules and activities like a Poker game (Kampker et al. (2014))

the steps of an assembly task were laid out as numerated boxes. The number on each box represents the position of the corresponding step in the assembly sequence. The game could be played as an individual or a group game. A player will throw the dice to determine how many cards he can receive from a neutral player called "bank". Then the player needs to decide the card position and whether they're creating the right sequence or not. If the right decision is made, the player will receive double the points that they bet in advance, otherwise, they lose the points.

The result showed that the approach brought a promising result. In comparison to the group who finished a conventional training, on average the "Sequence Poker" training group achieved a higher score of 1.09 questions.

One recent work with the combination of Gamification and Augmented reality to support the warehouse process with order picking (Bräuer and Mazarakis (2018)). Even though it is not an assembly task, this work is a very rare investigation about isolated individual game design elements' effectiveness. For order picking, the user must navigate through the warehouse in the specifically designed path and follow a fixed sequence of actions. Therefore, to some extent, it shares the nature of procedural work such as assembly. The design elements which are under investigation are leader board and badge.

The participants use also the Microsoft HoloLens to pick up 10 orders in the warehouse. After each picking, the user will either receive their performance feedback displayed on a leader board, receive a badge or nothing (no gamification support). Results revealed that the gamification is significantly improved user performance and motivation in opposition to non-gamification design. However, the effectiveness of each game design elements (leader board compares to the badge) remains unanswered.

## 4. CHALLENGES

Apart from fancy promising effectiveness of changing people's behaviors by good motivation and engagement, the use of gamification in industrial production is far from matured or beyond the lab-based trial. In this section, we discussed the major challenges that need to be solved for gamification to be successful in the industrial area.

### *4.1 Gamification as a design process*

In fact, gamification is often interpreted as simple as integrating points, high score lists into existing non-game settings. This is simple, easy to implement and little effort to investigate the user or process. Countless examples have proved otherwise (Kleinberg (2012)). That's why despite all its benefits, gamification is predicted to fail to live up to its expectations (Burke (2013)). For that reason, gamification should be considered as a design process rather than an add-on component. The underlying contexts and goals of each specific industrial use case should be analyzed and be the requirements for design. In other words, the user-centered design approach is essential for gamification to satisfy these goals.

### *4.2 Design for intrinsic motivation*

A usual choice of gamification is the utilizing of external prizes. It is evidently reflected through all the gamification examples in section 3: using extrinsic rewards, points, leader boards, and badges. Because of the easy-to-implement nature, sometimes they are used too liberal. As McGonigal states in her book "Reality is broken", underutilization can lead to boredom and a feeling of lacking appreciation (McGonigal (2011)). And this is raising an ethical question in academia.

"Overjustification" is a term in psychology to describe the situation where a high intrinsic motivated person gets demotivated by extrinsic recognition (Groh (2012)). Once the user gets used to received rewards, the absence of it potentially may promote negative effects. The mechanism of rewards or leader boards to push competition is controversial. As Niesenhaus put is: "It does not only generate winners but also losers" (Niesenhaus (2013)). To mitigate the negative effects, he suggested promoting rewards for team collaboration rather than for competition. Consequently, it demands a shift in mindset from designing for extrinsic motivation to intrinsic motivation.

## 5. FUTURE WORKS

While the requirements and challenges are put up, it is still missing a guideline for designing gamification in

the industrial sector. This struggle definitely will not be solved easily by borrowing any design framework from other domains. With the intention of doing so, studies to capture the effectiveness of different game design elements need to be conducted. Which affect one will create? Which emotion one will provoke?

Gamification, in fact, is all about design for people's motivation and engagement. Thus, gamification can be personalized and tailored based on one's preferences for the best result. However, this aspect is not considered in any design yet. Instead of rewards, a personalized design can stimulate one's engagement and motivation. Therefore, it addresses partially the second challenge in section 4.

## 6. CONCLUSIONS

As it has been pointed out, while gamification is transcending the traditional boundaries between work and fun, the production domain still has not been influenced. However, a couple of preliminary works have been indicating promising results. It is a good indicator that industrial organizations are open to cultivating new approaches in human-machine-interaction like gamification. This will provide confidence for practitioners to tackle the challenges in this particular domain.

In this paper, we provided an overview of gamified AR training systems for industrial production segment together with its challenges and future works. It first showed that gamification applications in production operations are relatively nascent. As gamification is mostly seized in process-oriented work types such as data management, team collaboration rather than the technical aspects, the available applications exemplify the new movement. Yet they are mainly in the experimental stage, within laboratory settings and small scale. It, therefore, requires more effort to opt for comprehensive solutions. Nevertheless, there would be no panacea. A comprehensive solution would be the one that bears in mind the organizational, contextual conditions as well as user needs.

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