Design Approaches for the Gamification of Production Environments. A Study Focusing on Acceptance

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ABSTRACT
Gamification is an ever more popular method to increase motivation and user experience in real-world settings. It is widely used in the areas of marketing, health and education. However, in production environments, it is a new concept. To be accepted in the industrial domain, it has to be seamlessly integrated in the regular work processes.

In this work we make the following contributions to the field of gamification in production: (1) we analyze the state of the art and introduce domain-specific requirements; (2) we present two implementations gamifying production based on alternative design approaches; (3) these are evaluated in a sheltered work organization. The comparative study focuses acceptance, motivation and perceived happiness.

The results reveal that a pyramid design showing each work process as a step on the way towards a cup at the top is strongly preferred to a more abstract approach where the processes are represented by a single circle and two bars.

Author Keywords
Gamification; assistive technology; computer-assisted instruction; augmented reality; human machine interaction

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INTRODUCTION AND MOTIVATION
A common definition of gamification is: the use of gaming elements to improve user experience and user engagement in non-game services and applications [4].

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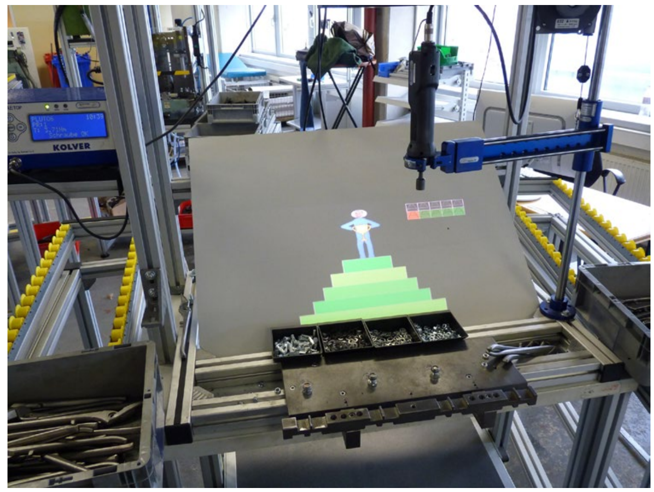

Figure 1. Gamified workplace. The visualization of the production process is projected in front of the worker.

However, gamification is just a new term for an established process where methods from gaming are adapted and used in other areas. The results have been called “edutainment” in the nineties, later “serious games” or “applied games”. This long tradition, especially in education and health (see background section) can be used if gamification is applied in industrial production.

The concept of gamification is broader than its predecessors as it potentially includes non-digital processes – a system of adding up points for sales, creating a leaderboard and then providing an incentive for “top performers” can be seen as gamification. However, here we focus on a form of gamification using not only use a computer but also motion sensors to generate automated real-time feedback.

Such rapid feedback is important because gamification in production needs to be integrated in existing assistive systems that generate other benefits more closely linked to the production domain (see requirements section).

The setup for providing projected real-time feedback based on motion recognition in production environments has been described in previous work [12, 13]. For this reason this work focuses on the description of how the gamification was realized (see implementation section).

Thus our work’s contribution to the topic of gamification in production environments has three components:

1. We discuss the special requirements when applying gamification to work in industrial production.
2. We present two implementations of gamification differing in design (Figures 1, 5, 6).
3. Finally we present a comparative study conducted in sheltered work organizations comparing the acceptance of the two implementations.

STATE OF THE ART

Although the term "gamification" is comparatively new, the state of the art in this area is vast if the work on serious games is included in the discussion. There are numerous examples of serious games in education, business and health. On the other hand there currently is hardly any work (apart from the authors') on gamification in the production industry.

Gamification in Education

It was in educational contexts the term "serious games" was established for learning software with multimedia elements and small educational games. This origin is natural, since "learning games" are probably as old as institutionalized learning itself: countless illustrated stories and mnemonic tricks show that pedagogy and games are strongly related.

A recent meta-analysis of serious games [21] provides a good overview of definitions, comparison criteria for serious games in education and an overview of 39 studies. In the context of the gamification of production, educational games may be advantageous in respect to support processes like training and presenting instructions. However, if gamification is fully integrated in the work processes the workers' focus mainly stays on the operative production tasks, so there are few design overlaps with serious games, which usually demand the users' full attention.

Gamification in Business

There have been several efforts to integrate gamification into business processes. In 2009 Reeves & Read described the "ingredients" to gamify work and increase engagement [16]. Their work maps elements from game design like avatars, leaderboards, leveling and reputation to business processes. However, in a more general understanding of gamification, regular business paradigms like "management by objectives" already implicitly use typical gaming elements as missions and goals have to be stated explicitly to make them transparent and measurable.

Thus it is not surprising that gamification was well received in business contexts: in 2011 Gartner predicted that 70 percent of Global 2000 businesses will manage at least one "gamified" application by 2014 [20]. Such predictions become more reasonable, if gamification is primarily considered a visualization of management by objectives.

The fascination for the gamification approach in general business contexts seems to be fueled by the increased measurability. Given the good measurability of production work it is surprising that gamified systems have not been implemented there so far. One reason might be the fear to take focus away from the production process.

Gamification in Health

Like education, health is an area where repeated exercises are required for success. So in learning as well as in training or rehabilitation, motivation and the ability to tolerate some repetitiveness are key success factors. Thus it was a natural step from serious games to games for health or "exergames" (a portmanteau of "exercise" and "games").

Probably the best-known health game is *Re-Mission* which was developed in 2007 – a shooter game where children with cancer could actively fight against virtual tumor cells. Playing the game led to a significantly higher reliability in the children's medicine intake [6]. It is an example of a health game that does not involve exercise activities but aims to change an attitude or achieve a psychological effect.

With the development of various body-related sensors (Sony EyeToy in 2002, Nintendo Wii in 2007, Microsoft Kinect in 2010) many health games became more physical. The effects were promising: an analysis of efficacy between traditional and videogame-based balance exercises showed positive evidence for the latter [2].

The interesting aspect about motion control in exergames is that the interaction becomes implicit or "natural": the user's body becomes the controller. This makes exergames a predecessor for the gamification of production, since in both areas the user is more efficient in moving and working if he or she does not have to explicitly interact with regular interfaces like mouse or keyboards.

One of the first motion-controlled exergames with markerless human body tracking was *motivotion60+* (Figure 2). It includes several gamified balance and strength exercises helping senior citizens to prevent falls [1].

Figure 2. motivotion60+ is an exergame which already uses markerless motion tracking for implicit interaction.

Like assistive systems in production the *motivotion60+* system adapts based on the user's performance which allows a comparison of motion-based assistance in exergames and motion-based assistance in production contexts [9].

Next to the technical parallel between gamification in health and production (both use motion tracking) there is also a parallel with regard to design: the concept of flow [3] – a state of total engagement in an activity – has been proposed as an adequate matrix for exergames [19]. This approach has also been adapted in the first attempt towards a gamification of production [8] which is summarized below.

Gamification in Production

The first concept in this area was presented in 2012 [8] and strongly drew from the concept of flow. It introduced a motion-controlled gamification component with a visual output strongly resembling the Tetris game (Figure 3).

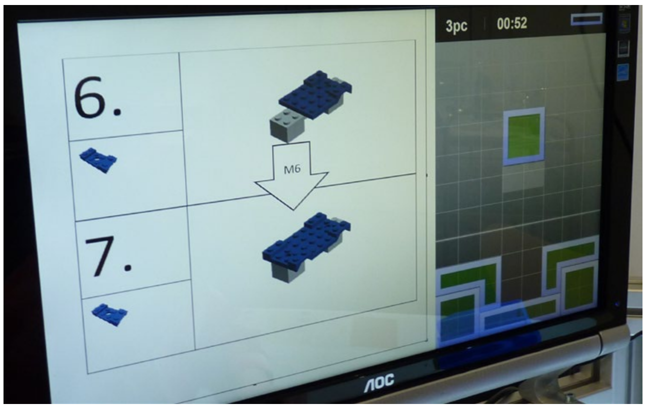

Figure 3. The first attempt to gamify production uses a monitor to visualize work processes as Tetris blocks.

This concept was adapted to support the gamification of assembly processes (Table 1) and the approach can principally still be used for future implementations.

Table 1. Flow: Condition and implementation

Flow Condition	Implementation
being involved in an activity with a clear set of goals	(i) macro level: complete a (flawless) assembly sequence (ii) micro level: complete the active process (brick movement) as quick (green) as possible
good balance between perceived challenges and perceived skills	(i) starting difficulty level based on average user competence (ii) adjustable process durations (e.g. shorter durations / more demanding sequences)
task must have clear and immediate feedback	(i) color changes and shadowing dual-code visual feedback (ii) (optional) sound integrates another sensory channel
the activity is intrinsically rewarding	(i) on the micro level "getting a brick down" quickly is immediately pleasing (ii) the final visually pleasing disintegration of the built brick sequence appeals to the basic human desire for order and completion

While this pioneering approach was already accepted by the production workers, it still was shown to suffer from several design shortcomings, especially a visual complexity too high for many users in production environments [7, 10]. For this reason future approaches to gamify production need to ensure a low cognitive demand which introduces the section requirements.

REQUIREMENTS FOR THE PRODUCTION DOMAIN

As stated in the business part of the state of the art section, it is surprising that gamification did not already spread into industrial production. Production processes have physical outcomes which usually are already measured. Thus common gaming elements like progress visualization, scores and leaderboards could be implemented with little effort. Obviously there are certain demands specific to this domain which previously prevented the use of gamification. In this section we discuss which requirements (R) are specific for gamifying production environments.

R1: low cognitive workload for gamification

In opposition to games or computer-based office work the user's default focus in production work is not a software but the physical product itself and several machines and tools. This induces a dilemma: gamification elements might distract the user from the main work focus. This potential problem results in two derived requirements:

R1': keep the visualization of gamification simple

Moving elements as well as complex graphical structures and animations should be avoided.

R1'': avoid explicit interaction with gamification elements

Activities which need the full attention of the user e.g. using a mouse to select an item or the keyboard to enter text should be avoided.

R2: support implicit interaction with gamification elements

As described in the state of the art section, implicit interaction using motion recognition has been established in exergames and found its way into a pioneering system for the industrial domain. R2 partly addresses R1'' as it helps to minimize interaction with mechanical controllers.

R3: project gamification elements close to locus of control

The pioneering gamification approach still used a monitor to display the elements. However, with R1 und R2 in mind it is obvious that distraction from the center of interaction should be reduced. This can be achieved by following one of Shneiderman's Golden Rules and support the internal locus of control [18] by moving information in the proximity of this locus, i.e. "in situ". As the use of projection has been established in office work over 15 years ago [15] it was shown that by now this technology is robust enough to be applied in the industrial domain [12, 17].

R4: detect emotional impact of gamification

For adapting gamification elements it would be beneficial to know a user's emotional state. This allows to discriminate between behaviors with similar consequences (e.g. faster production) but different causes (e.g. stress versus joy). This requirement could be addressed by using galvanic skin sensors or by analyzing facial expressions.

IMPLEMENTATION

In this section we present two implementations which gamify industrial production processes. The use of motion recognition to address requirement R2 and the use of projection to address R3 have been described in previous work [8, 13]. Here we focus on the comparison of two implementations based on the same technology but applying different design approaches.

Physical Integration

The overall aim was integrating the gamification elements into the users' regular work environment and close to their natural locus of control (R3). The gamification elements were projected to the right of the user in implementation 1 (Figure 4, left) and in front of the user in implementation 2 (Figure 4, right).

Figure 4. System 1 (left, Circle & Bars) projects the gamification elements to the user's side while system 2 (right, Pyramid) projects them behind the work area.

Both forms of integration did not require changing the workplaces' regular setup. We only had to integrate a wood board with projection-friendly white varnish.

Gamification Design

On the level of design the implementations were named according to their characteristics. The first was called "*Circles & Bars*" (*C&B*) and the second "*Pyramid*". Both visualize processes (i.e. work steps) and sequences (i.e. a sequence of steps resulting in a pre-product).

Both implementations use the color-coding established in the state of the art to visualize the progression of time: the current work process starts in dark green and slowly changes color to yellow, orange and finally red. The duration of that color change is derived from the mean of several calibration runs, so it is user-specific.

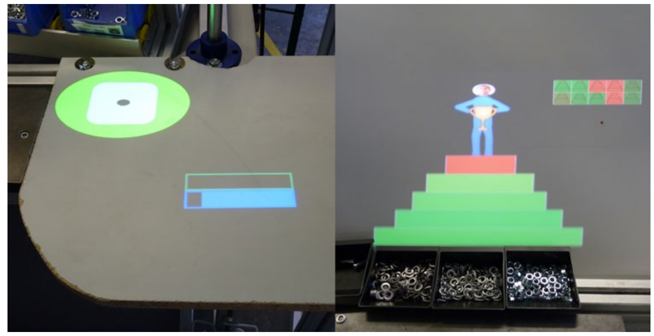

Figure 5. The Circle & Bars implementation (left) uses just a single circle for the current work process. The Pyramid implementation (right) provides an overview of the steps.

C&B (Figure 5, left) uses a single circle to represent the current work process. It encircles a die showing the process number. Additionally to the color change the circle's radius permanently decreases. Next to the circle there are two bars. After each completed work step, a fixed ratio of the remaining circle area is added to the green sequence bar. However, if there was a mistake, nothing is added to the bar.

In *Pyramid* (Figure 1; Figure 5, right) it is the color of the step the user figure currently stands on that changes the color. At the end of a sequence the visual result is a pyramid with one colored plateau per process (Figure 1). If there was no mistake, the figure reaches the cup on the pyramid's top. The importance of reaching this goal is heightened by (optionally) personalizing the figure's head with a photo of the worker. A completed pyramid is moved up to the board on the top right while its color is changed to show average performance: if half of the processes were done quickly (= green bar) and the other half slowly (= red bar), the resulting pyramid is colored orange. However, the pyramid is always completely red if a mistake was made. Table 2 provides an overview of the main differences:

Table 2. Comparison of gamification approaches

Feature	Implementation 1: Circle & Bars	Implementation 2: Pyramid
position of projection	to the right of the workspace	behind the workspace
indication of current process	pips on a dice	position of figure on pyramid steps
total number of work steps	-	number of steps of the pyramid
progression of time	color and size of the circle	color of a pyramid step
indication of an error	color and size of the circle	color of the step and removal of cup
previous processes	green bar (no quality feedback)	pyramid board (with quality feedback)
previous sequences	blue bar (no quality feedback)	pyramid board (with quality feedback)

STUDIES

The studies were conducted to observe and analyze how workers in production accept the augmentation of their regular workplaces by different forms of gamification.

Setting, Test Population and Setup

Both systems were evaluated at the German sheltered work organization GWW Gemeinnützige Werkstätten und Wohnstätten Sindelfingen) which provides over 1.300 workplaces for impaired persons.

For implementation 1 the test population was 10 impaired users; system 2 was tested with 14 impaired users. In both cases the users' task was to assemble metal shears in 5 work steps each. We used a repeated measures approach with 10 assembly sequences with gamification and 10 sequences without gamification. The order of the conditions was counterbalanced.

As we focused on the acceptance of the different design approaches we used a Wizard of Oz approach for the technical setup, so the time measurement and the real-time error detection was performed manually by a supervisor using the image of a video camera above the workplace.

Procedure

In both setups we measured the user experience with an identical questionnaire based on the system usability scale [14] with a Likert scale ranging from 1 to 5.

Before the experiment, we evaluated the attitude towards the experiment as well as the physical and mental state. This is especially important with impaired persons because they can be subject to strong changes within just a few hours.

We also used rephrased questions to counter-balance affirmative tendencies or problems with comprehending the questions. We found that there were no significant differences between the two test populations.

The questions posed were deliberately kept simple, so impaired persons (and everybody else) is not confused by technical terms. Also the questions were elaborated on and rephrased by the supervisors.

1. I liked the game.
2. The game disturbed my work.
3. The game motivated me to get better.
4. The game made me happier.

Questions 1 and 2 were constructed to be mutually exclusive, as the pre-study proved that the workers like their work.

Results

Although some subjects expressed unease or uncertainty at the beginning, the pre-evaluation showed that in both studies all participants were motivated and in a good mood, so the results can be attributed to the different implementations.

The mean approval rate was 4.5 (SD = 0.7) in *C&B* and 4.8 (SD = 0.6) in the *Pyramid* group. The workers would not accept or "like" a game that disturbed their work.

Figure 6 provides a highly aggregated perspective of the results. For better comparability the bars are in percent. 100% in *Pyramid* represents 14 participants and 10 in *C&B*. Dark green in this diagram means very high acceptance (5), light green good acceptance (4), yellow marks a neutral attitude (3) while orange (2) and red (1) indicate rejection.

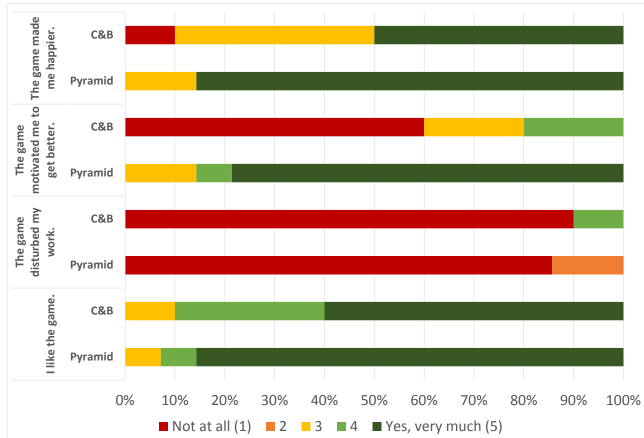

Figure 6. Acceptance level of the two gamification implementations on a scale from 1 to 5 with all participants.

The general trend is obvious: in all questions the *Pyramid* approach was clearly preferred to the *C&B* approach.

We will now analyze the results in more detail, looking at the mean acceptance rate with standard deviation and using a t-test to determine if the differences between the two approaches are statistically significant.

Table 3. Comparison of Acceptance

Question	Mean Acceptance (SD)		Significant Difference
Approach	***C&B***	***Pyramid***	***C&B* vs. *Pyramid***
I liked the game.	4.5 (0.7)	4.8 (0.6)	$p > 0.154$ not significant
The game disturbed my work.	1.3 (0.9)	1.2 (0.3)	$p > 0.314$ not significant
The game motivated me to get better.	1.9 (1.4)	4.4 (1.1)	$p < 0.001$ highly significant
The game made me happier.	3.5 (1.8)	4.7 (0.7)	$p < 0.037$ significant

Discussion

When looking at Figure 6 it seems obvious that the *Pyramid* is preferred to the *C&B* implementation. However, this preference is not statistically significant. There also is no significant difference regarding the work disturbance: both implementations seem to cause almost no recognized disruption. Still the *Pyramid* approach has a much lower standard deviation so the whole group seems to agree while in *C&B* there is a more diverse range of opinions.

However, with regard to the acceptance rates, both implementations represent an enormous improvement over the previous state of the art discussed in the sub-section 'Gamification in Production'. In the production Tetris approach the mean approval rate was 2.0 (SD = 0.4), so the acceptance of both implementations presented here is higher than the acceptance of the Tetris approach. In both cases the difference in acceptance is highly significant ($p < 0.0000001$ for *C&B* and $p < 0.0000000000001$ for *Pyramid*).

The question regarding motivation provides the comparative study's clearest result: with a high statistical significance the *Pyramid* is preferred to the *C&B* approach. The interviews showed that is due to three effects:

- the colorful pyramid with several steps is more concrete than the single abstract sphere
- the user figure increases the level identification
- the optional integration of a personal photograph as the figure's head (which was opted for by 13 of 14 test subjects) further increased identification
- the cup at the pyramid's top level was a vivid gamification element generating surprisingly strong emotions when won or lost

This positive effect on the overall motivation probably also influenced the last question regarding the test subjects' happiness after using the gamified workplace. Again the *Pyramid* is preferred to the *C&B* approach and this preference is statically significant.

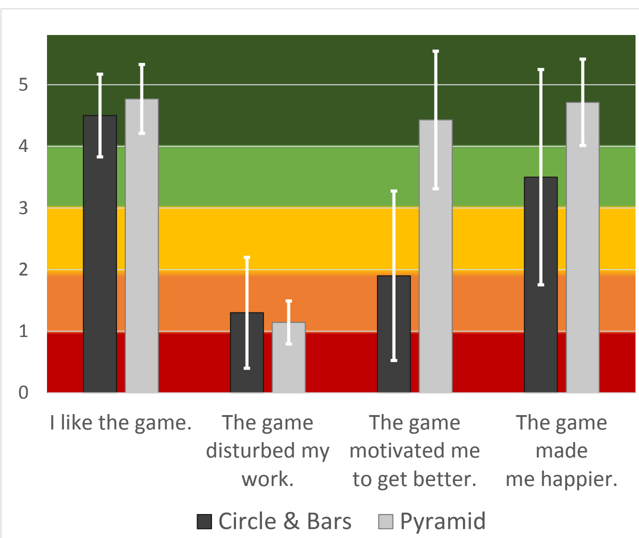

Figure 7. Acceptance level of the gamification approaches as a bar chart with indicated standard deviations.

Like in the question regarding work disturbance (SD = 0.3 in *Pyramid* and SD = 0.9 in *C&B*), the standard deviation is much lower in the *Pyramid* approach (SD = 0.7 versus SD = 1.8 in *C&B*) which shows that this effect is perceived homogenously throughout the group. As Figure 7 illustrates, the lower standard deviation in the *Pyramid* approach applies to all questions.

CONCLUSION

Research on the potentials of gamification of production is just beginning. We explained how gamification in this domain is related to previous work from other domains like education, business and health; we highlight the synergetic effects of using motion recognition for implicit interaction both in the gamification of health (exergames) and for the gamification of production.

Based on the previous state of the art in gamified production and our research we derived 4 general requirements for gamified work in this domain. We then described two alternative implementations which address previous shortcomings. Both implementations were evaluated in a study at a sheltered work organization.

The results showed that the vivid *Pyramid* implementation is clearly preferred to the more abstract *Circle & Bars* implementation. In spite of the higher visual complexity, this design approach is perceived to generate almost no work disturbance. This low cognitive load was achieved by avoiding moving parts. Also the *Pyramid* implementation resulted in significantly more perceived happiness after work and highly significantly more motivation.

While the cup on the pyramid's top may not yet represent the holy grail of gamified production, we still think that the approach is a reference point for future work in this area.

FUTURE WORK

The requirement R4 (detect the emotional impact of gamification) could not be addressed in the implementations presented here and remains an issue for future work.

While this work focused on the acceptance of gamification at production workplaces, an important issue in this domain is the quantitative impact of gamification on task completion time and error rate. A first systematic discussion comparing such quantitative effects of different gamification designs has been established recently [11]. However, this work does not take into account the pyramid-design portrayed here, which proved to be most highly accepted gamification design in production environments so far.

An important next step will be a long-term study to check if the positive effects and the high acceptance rates will prevail or perish in everyday work life. Recently the concern was raised that replacing intrinsic rewards with explicit ones may in the long run reduce work motivation [5]. This shows the ethical dimension of using gamification and raises a question which should also be investigated in a long term study.

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