Gamification of assembly routines: Planned user study evaluating a level system with customized feedback elements

Jessica Ulmer [1], Sebastian Braun[1] and Jörg Wollert [1]

[1] *FH Aachen University of Applied Sciences, Goethestrasse 1, Aachen, 52078, Germany*

Abstract
Enterprise gamification is a promising approach to motivate employees and increase work output. Game elements, such as point displays, are added to traditional work environments, transforming them into game-like systems. However, user studies are mainly conducted in educational scenarios, while gamification effects in work environments remain unclear. This work-in-progress paper presents the background and the setup for a user study analyzing the impact of a combined level and feedback system on the users' motivation and work efficiency. An Augmented Reality (AR) workstation is used to assist an assembly routine with industrial profiles. Two groups are formed: The Non-Gamified-Group conducts the assembly training using static AR-projections on the work desk. The Gamified-Group executes the assembly training in four difficulty levels and can select feedback elements from a predefined list.

Keywords
Gamification, Manual Work, User Study, Level System

1. Introduction

Gamification, the use of game elements in non-gaming contexts [1], is on the rise in production environments. Researchers and companies aim to increase satisfaction and work output by offering more meaningful work content, individual feedback, and engaging elements [2, 3]. Different ideas exist on how to gamify work environments; for instance, leader boards replace traditional status displays, and points can be collected throughout work procedures [4, 5].

However, most studies analyzing the effects of gamification on user performance and motivation are currently done in the educational context [6–8]. Here, student groups are used to analyze specific game elements or complete gamification approaches compared to traditional learning scenarios. Often, online learning platforms are used to implement and evaluate gamification strategies. Although these studies show promising results regarding learning motivation and output [6, 9], it is unclear if these results can directly be transferred to industrial scenarios. Thus, novel studies focusing specific requirements of industrial applications are required to provide recommendations to companies.

This work presents a study setup used to analyze the impact of a level and feedback system on an AR-assisted assembly training. The selected assembly routine is seen as an exemplary application for manual work which is also found, for instance, in maintenance routines. Corporate online trainings, similar to the learning platforms of schools and universities, are not targeted.

For the study, display options of a traditional AR manual workstation are expanded by different game elements such as a timer, a progress bar, and a quality indicator. The feedback elements are selectable by each user to increase their meaningfulness and to raise the users' awareness. Moreover, four difficulty levels are implemented to stepwise increase the assembly complexity according to the user's performance.

1st Interdisciplinary Conference on Gamification and Entrepreneurship (StartPlay), 2022, August 05–06, 2022, Koblenz, Germany
EMAIL: ulmer@fh-aachen.de (A. 1); sebastian.braun@ fh-aachen.de (A. 2); wollert@ fh-aachen.de (A. 3)
ORCID: 0000-0001-9185-9352 (A. 1); 0000-0002-3821-7227 (A. 2); 0000-0001-7576-1339 (A. 3)

2. Related work

The following literature review focuses on current applications in education and production environments and approaches to adapt gamification elements according to the users' preferences.

2.1. Gamification in education

Gamification approaches have been applied widely in different educational scenarios [8, 10], showing the possibility to enhance learning experiences and improve learning outcomes [9]. Cassells et al. [11] investigated the effects of feedback loops, onboarding elements, and an interactive interface on students' enjoyment during prioritization tasks. They found an increased intrinsic motivation and enjoyment of the students compared to a non-gamified prioritization process. Jurgelaitis et al. [12] examined the effects of a gamified UML modeling course on a virtual learning platform. Their gamification approach included a level system, different rewards, a leaderboard, content locking, and trading. The gamified course led to improved grades and increased positive motivation.

Although studies in the educational environment show promising results regarding the positive effects of gamification, applications and studies focusing on industrial tasks remain rare.

2.2. Gamification in production

Companies introduce different measures to increase work outcomes and motivate their employees [13], while enterprise gamification is seen as one possibility to create human-centered work environments [14, 15]. In production systems, game elements can provide real-time performance feedback to users or groups [16, 17]. This approach can be included easily in existing work environments by adding sensors and showing dashboards to the employees. Studies indicate that gamified feedback can push participants to evaluate their performance [16] and increase productivity [18].

Liu et al. [19] proposed to use gamification approaches for machining job preparations on smartphones. They included competitions for typical tasks, freedom of choice for the order fulfillment, and feedback using points and badges.

Bräuer et al. [20] applied a leaderboard and badges to an order picking environment. In their study, the leaderboard decreased the task completion time; however, it also reduced the test persons' feeling of autonomy and competence. The badges had no positive influence on the picking times and resulted in a decreased feeling of autonomy. Nguyen et al. [17] introduced points and a progress bar into an AR-supported assembly environment. Their study with 22 participants showed no significant engagement difference between gamified and non-gamified AR applications.

2.3. Customized Gamification

Often, gamification approaches are designed as a one-fits-all approach meaning that all users receive the gamification elements independently from their individual motivations and preferences [21]. Studies in the educational area show that the impact of gamification depends on several factors, such as personality, demographics, or individual traits [22]. Therefore, different ideas and methods exist to tailor gamification approaches to the needs of individual users. This approach should increase the positive effects of gamification and prevent negative outcomes. If gamification environments are changed automatically based on user information, the term "personalized gamification" is typically used [23]. If users adjust the environments according to their preferences, this approach is specified as "customized gamification" [24].

In this study, the customization approach is selected. Studies show that this selection method partially matches automatic selection strategies according to player types [24] and can increase work performance. Schubhan et al. [25] offered a group of end-users to design their preferred gamification concept for an image tagging task. Afterward, they compared this customized approach to fixed gamification settings and a non-gamified version. They found that the customized approach led to more generated tags, although the quality was lower than in the non-gamified group. Tondello and Nacke [24] compared the task performance of a group using selectable game elements to a group with generic game elements. As a result, the group using customized gamification had an increased performance regarding the number of tagged images but no significant difference regarding motivational aspects. Moreover, they found significant relations between user Hexad types and the selected game elements.

3. Study design

This study aims to evaluate the impact of a level system and selectable feedback elements on user performance and motivation using quantitative and qualitative data. In contrast to existing work (section 2), an assembly process using industrial components in a manual work environment is targeted. For the analysis, a significance level $\alpha=0.05$ is chosen.

3.1. Aims and hypotheses

According to previous work in non-industrial environments (section 2), it is possible to increase performance, engagement, and learning using gamification elements. Moreover, we expect that the level system increases the participants' learning and the perceived usefulness. Therefore, the following hypotheses are formulated for this study:

H1: Participants of the Gamified-Group conduct the final assembly faster than participants of the Non-Gamified-Group.

H2: Participants of the Gamified-Group commit fewer errors in the final assembly than participants of the Non-Gamified-Group.

H3: Participants of the Gamified-Group complete more assembly iterations than participants of the Non-Gamified-Group.

H4: Participants of the Gamified-Group are more engaged in the task than participants of the Non-Gamified-Group.

H5: Participants of the Gamified-Group rate their learning progress higher than participants of the Non-Gamified-Group.

H6: Participants of the Gamified-Group find the system more useful than participants of the Non-Gamified-Group.

3.2. Study setup

The study setup is based upon previous work regarding AR-supported work stations [26] and gamification of manual tasks [5, 27, 28]. Students and employees of the FH Aachen University of Applied Sciences of the department of manufacturing and mechatronics are targeted as participants. Participation in this study is not related to an incentive scheme; however, the students are allowed to substitute one practical session by participating in this study.

In general, the participants are asked to execute an AR-supported assembly routine at least three times before answering a questionnaire. They are free to execute the assembly routine more than the three runs. After answering the questionnaire, the participants are asked to assemble the structure one last time without any support.

3.2.1. Assembly task

For this study, an assembly routine using industrial profiles to create a dog-shaped structure is used (Figure 1). The dog-shaped structure is selected as it requires the handling of industrial items in combination with a tool, includes non-self-explanatory procedures, and offers the possibility to commit errors. In contrast to previous applications [28, 29], the participants are not asked to assemble the whole dog-shaped structure but only one side to decrease the assembly time. Thus, the participants must place and mount eleven parts which takes around 10 minutes. An Allen key is required for the mounting operation while the screws and nuts are integrated into the parts so that no small items must be handled.

Figure 1: Dog-shaped assembly used for this study.

3.2.2. Work environment

A standard manual workstation enhanced with AR projections, a monitor, and a pick-by-light system is used [26]. The AR projections present 2D information in the user's working area. The pick-by-light system highlights the next boxes using green LEDs and shows errors using red LEDs. The monitor is used to rotate a 3D image of the dog-shaped structure as a reference during assembly. Moreover, the picking of tools and grabbing objects out of small load carriers is detected. Therefore, a LiDAR sensor and a tool holder are used. A mounting for the dog-shaped structure simplifies the assembly operation and specifies the assembly position (Figure 2). The mounting also includes a white projection surface.

The evaluation system [28] compares the user's actions to the planned work steps. In case of errors, the user is notified by red warning messages, and error resolving strategies are provided [27]. Currently, the sensor system only detects pick operations. As place and mount operations cannot be identified automatically, manual checking of assembly operations by the participants is used. Therefore, a button is integrated to acknowledge finished assembly and mount operations.

Figure 2: Dog-Shaped assembly with mounting at the manual work station.

3.2.3. Gamification elements

Two gamification strategies are combined for this work: The level system should adjust the work difficulty according to the user's performance. This way, users should neither be over- nor under-challenged during the assembly to keep the task interesting and increase engagement. The feedback system should provide information about the users' progress compared to predefined time indicators and quality rates. Moreover, the feedback system should highlight progress in comparison to previous runs.

For the level system, a successive reduction of assembly information is used during pick, place, and mount operations. Level changes are triggered after completing an assembly if the quality rate is over 80% and the time requirements are met in at least 80% of the cases. In level 1, the pick-by-light system indicates the box for the required item while the part's 3D image and name are shown in the working area. During place and mount operations, the targeted location and the location of the part in the whole assembly are indicated. In the case of complex tasks, animations are shown to explain the correct handling of objects and tools. In level 2, the part name and the highlighting of complex tasks are removed. In level 3, only the part's 3D view is shown during pick operations. For assembly and mount instructions, the users receive information about the part's location in the whole assembly but no further indication of the location in their assembly. In level 4, no support is provided to the users during the predefined time intervals. If the users exceed the target times, information is provided as defined in level 2.

The user performance is evaluated according to the time and quality of the assembly task. Thus, the game elements should represent these performance indicators as well as the users' general progress. As immediate feedback can increase encouragement for a task [30], a mix of immediate feedback messages and feedback for the whole assembly routine is used for this study. For all participants, a progress bar indicates the number of finished steps in comparison to the total number of steps (Figure 3). After each correct action, green pop-up messages appear. Also, conclusions of each work task regarding time and quality as well as level up messages are provided. In addition, the users can create their personal feedback cockpit using different status indicators:

- Circular progress bar for quality rate,
- Circular progress bar for timely actions,
- Timer for remaining time,
- Point display,
- Level display.

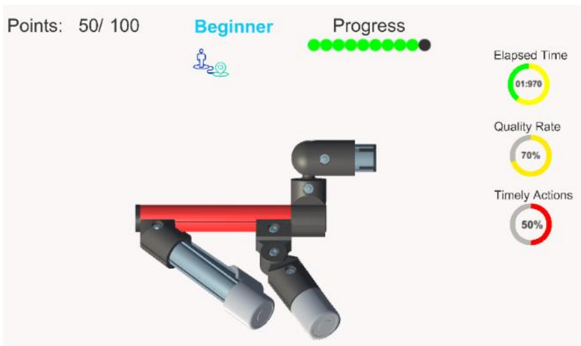

Figure 3: Exemplary AR projection including feedback elements.

3.2.4. Performance indicators

During the assembly routines, time and quality of each action are recorded. Moreover, the number of improvement actions and the number of assemblies per person are collected. These indicators are used to evaluate H1, H2, and H3.

3.2.5. Questionnaire

For all participants, statistical information about their age, gender, handicraft training, and personal estimation of manual skills is collected. Moreover, previous experience with industrial profiles is retrieved.

After the assembly operation with the AR projections, the participants' motivational aspects are accessed using an Intrinsic Motivation Inventory (IMI) with a 7-point Likert scale [12, 31, 32] to examine H4. For the IMI, the categories "interest/enjoyment", "perceived competence", "effort/importance", "pressure/tension", "perceived choice", and "value/ usefulness" are included. The personal view on the learning progress (H5) is accessed using a questionnaire with six elements developed according to the guidelines outlined in [33]. In this part, the participants rate their learning using a 5-point Likert scale, answering questions such as "How would you rate your learning progress during the assembly routine?" or "Do you feel that you have gained new skills during this session?". In order to analyze the usefulness of the gamified and non-gamified workstation (H6), the System Usability Scale (SUS) [34] with a 5-point Likert scale is selected.

After finishing the data collection phase, all categories of the IMI, the answers regarding the learning progress, and the SUS are checked for internal consistency using Cronbach's alpha [35].

3.2.6. Planned Procedure

The study starts with general information regarding the procedure and the voluntary nature of participation (Figure 4). Afterward, the Gamified-Group receives an explanation about the level system and selects their preferred status indicators. Before beginning with the assembly task, the functioning of the industrial connectors is explained using exemplary parts. Next, all participants are asked to assemble the dog-shaped structure at least three times while they are free to execute more times. For the Gamified-Group, the performance of each assembly routine is evaluated. If the requirements for a level-up are met, the level is changed accordingly. For the Non-Gamified-Group, the assembly information remains at level 1, independent from their performance.

After executing the assembly at least three times, the participants are asked to fill in the questionnaire. Finally, all participants should assemble the dog structure the last time without receiving support from the AR projections or the pick-by-light system.

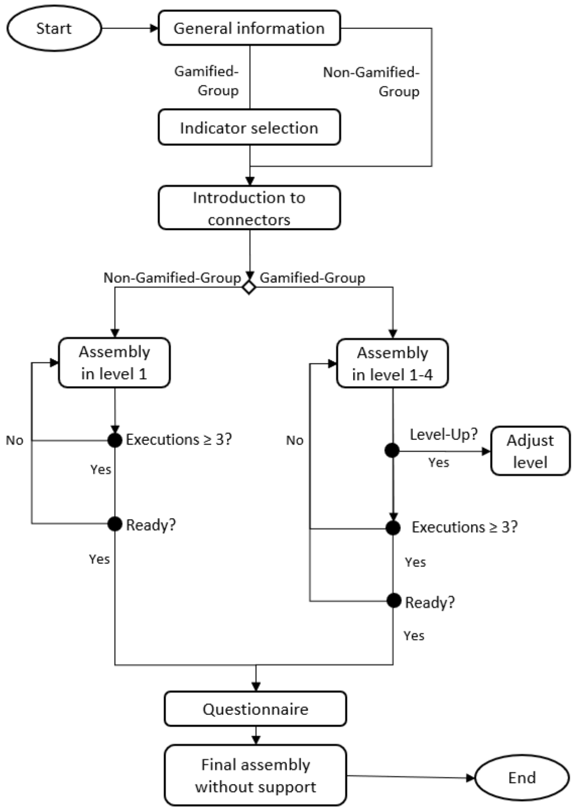

Figure 4: Planned procedure of the user study.

4. Conclusion and outlook

The presented user study aims to analyze the impact of gamification elements on users in industrial work scenarios. A manual workstation for the assembly of industrial profiles is selected as the use case. For the study, two groups are formed which must execute the assembly task at least three times.

The Non-Gamified-Group receives fixed assembly information regarding pick, place, and mount operations. They do not receive indicators for time or quality requirements but information if they commit errors.

For the Gamified-Group, the presentation of assembly instructions is changed according to the performance. Users who execute the assembly steps correctly and timely receive a level-up message and fewer assembly instructions in the following sequence. Users who have difficulties completing the assembly tasks remain at the current level. This way, boredom, and overload should be prevented. Moreover, users of the Gamified-Group can select different status indicators for their work environment. This approach should raise the users' awareness regarding game elements and offer some choice to the participants.

In the next step, a pilot test with ten participants will be conducted to ensure the proper working of the manual workstation and the comprehension of the questionnaire. The user study with at least 70 participants should take place in April 2022.

5. References

[1] L. Deterding, S., Dixon, D., Khaled, R., & Nacke, Gamification: Toward a Definition., in: CHI 2011 Gamification Work. Proc., ACM, Vancouver, BC, Canada, 2011: pp. 12–15. doi:10.1007/978-3-642-13959-8_1.

[2] B. Morschheuser, J. Hamari, The Gamification of Work: Lessons From Crowdsourcing, J. Manag. Inq. 28 (2019) 145–148. doi:10.1177/1056492618790921.

[3] N.S. Uletika, B. Hartono, T. Wijayanto, Gamification in Assembly Training: A Systematic Review, in: 2020 IEEE Int. Conf. Ind. Eng. Eng. Manag., 2020: pp. 1073–1077. doi:10.1109/IEEM45057.2020.9309791.

[4] B. Morschheuser, J. Hamari, K. Werder, J. Abe, How to Gamify? A Method For Designing Gamification, in: Proc. Annu. Hawaii Int. Conf. Syst. Sci., 2017: pp. 1298–1307. doi:10.24251/HICSS.2017.155.

[5] J. Ulmer, S. Braun, C.-T. Cheng, S. Dowey, J. Wollert, Human-Centered Gamification Framework for Manufacturing Systems, Procedia CIRP. 93 (2020) 670–675. doi:10.1016/j.procir.2020.04.076.

[6] K. Seaborn, D.I. Fels, Gamification in theory and action: A survey, Int. J. Hum. Comput. Stud. 74 (2015) 14–31. doi:10.1016/j.ijhcs.2014.09.006.

[7] S. Kim, K. Song, B. Lockee, J. Burton, Gamification in Learning and Education. Springer International Publishing, Cham, 2018.

[8] D. Albertazzi, M.G.G. Ferreira, F.A. Forcellini, A Wide View on Gamification, Technol. Knowl. Learn. 24 (2019) 191–202. doi:10.1007/s10758-018-9374-z.

[9] L. Anderie, Gamification, Digitalisierung und Industrie 4.0. Springer Fachmedien Wiesbaden, Wiesbaden, 2018.

[10] J. Hamari, J. Koivisto, H. Sarsa, Does gamification work? - A literature review of empirical studies on gamification, in: 47th Hawaii Int. Conf. Syst. Sci., 2014: pp. 3025–3034.

[11] T. Cassells, D.O. Brain, The Effect of Gamification on Intrinsic Motivation for Prioritisation, in: 2018 IEEE Games, Entertain. Media Conf., IEEE, 2018: pp. 1–11. doi:10.1109/GEM.2018.8516517.

[12] M. Jurgelaitis, L. Čeponienė, J. Čeponis, V. Drungilas, Implementing gamification in a university-level UML modeling course: A case study, Comput. Appl. Eng. Educ. 27 (2019) 332–343. doi:10.1002/cae.22077.

[13] D.H. Pink, Drive: The surprising truth about what motivates us. Riverhead Books, New York, 2011.

[14] European Commission. Directorate General for Research and Innovation, Industry 5.0: towards a sustainable, human centric and resilient European industry. Publications Office, 2021.

[15] J. Ulmer, S. Braun, C.-T. Cheng, S. Dowey, et al., A human factors-aware assistance system in manufacturing based on gamification and hardware modularisation, 2022.

[16] J. Ohlig, T. Hellebrandt, P. Poetters, I. Heine, R.H. Schmitt, B. Leyendecker, Human-centered performance management in manual assembly, Procedia CIRP. 97 (2021) 418–422. doi: 10.1016/j.procir.2020.05.261.

[17] D. Nguyen, G. Meixner, Comparison User Engagement of Gamified and Non-gamified Augmented Reality Assembly Training, in: A. Przybyłek, M. Morales-Trujillo (Eds.), Adv. Agil. User-Centred Softw. Eng. LASD MIDI 2019 2019. Lect. Notes Bus. Inf. Process. Vol 376., Springe, Cham, 2020: pp. 142–152. doi:10.1007/978-3-030-37534-8_8.

[18] O. Korn, M. Funk, A. Schmidt, Towards a gamification of industrial production, in: Proc. 7th ACM SIGCHI Symp. Eng.

Interact. Comput. Syst., ACM, New York, NY, USA, 2015: pp. 84–93. doi:10.1145/2774225.2774834.
[19] M. Liu, Y. Huang, D. Zhang, Gamification's impact on manufacturing: Enhancing job motivation, satisfaction and operational performance with smartphone-based gamified job design, Hum. Factors Ergon. Manuf. Serv. Ind. 28 (2018) 38–51. doi:10.1002/hfm.20723.
[20] P. Bräuer, A. Mazarakis, AR in order-picking – experimental evidence with Microsoft HoloLens, in: R. Dachselt, G. Weber (Eds.), Mensch Und Comput. 2018 - Work., Gesellschaft für Informatik e.V., Bonn, 2018. doi:10.18420/MUC2018-WS07-0463.
[21] I. Rodríguez, A. Puig, À. Rodríguez, Towards Adaptive Gamification: A Method Using Dynamic Player Profile and a Case Study, Appl. Sci. 12 (2022) 486. doi:10.3390/app12010486.
[22] A.C.T. Klock, I. Gasparini, M.S. Pimenta, J. Hamari, Tailored gamification: A review of literature, Int. J. Hum. Comput. Stud. (2020) 102495. doi:10.1016/j.ijhcs.2020.102495.
[23] G.F. Tondello, Dynamic Personalization of Gameful Interactive Systems, University of Waterloo, 2019.
[24] G.F. Tondello, L.E. Nacke, Validation of User Preferences and Effects of Personalized Gamification on Task Performance, Front. Comput. Sci. 2 (2020) 29. doi:10.3389/FCOMP.2020.00029/XML/NLM.
[25] M. Schubhan, M. Altmeyer, D. Buchheit, P. Lessel, Investigating User-Created Gamification in an Image Tagging Task, in: Proc. 2020 CHI Conf. Hum. Factors Comput. Syst., ACM, New York, NY, USA, 2020: pp. 1–12. doi:10.1145/3313831.3376360.
[26] J. Ulmer, M. Gröninger, S. Braun, J. Wollert, AR Arbeitsplätze, Atp Mag. 62 (2020) 60–67. doi:10.17560/atp.v62i10.2495.
[27] J. Ulmer, S. Braun, C.T. Cheng, S. Dowey, J. Wollert, Adapting Augmented Reality Systems to the users' needs using Gamification and error solving methods, Procedia CIRP. 104 (2021) 140–145. doi:10.1016/J.PROCIR.2021.11.024.
[28] J. Ulmer, S. Braun, C.-T. Cheng, S. Dowey, J. Wollert, Gamified Virtual Reality Training Environment for the Manufacturing Industry, in: 2020 19th Int. Conf. Mechatronics - Mechatronika, 2020: pp. 1–6. doi:10.1109/ME49197.2020.9286661.
[29] J. Ulmer, S. Braun, C.-T. Cheng, S. Dowey, J. Wollert, Gamification of virtual reality assembly training: Effects of a combined point and level system on motivation and training results, Int. J. Hum. Comput. Stud. 165 (2022) 102854. doi:10.1016/j.ijhcs.2022.102854.
[30] D. Garaialde, A.L. Cox, B.R. Cowan, Designing gamified rewards to encourage repeated app selection: Effect of reward placement, Int. J. Hum. Comput. Stud. 153 (2021) 102661. doi:10.1016/j.ijhcs.2021.102661.
[31] Center for Self-Determination Theory. Intrinsic Motivation Inventory (IMI). https://selfdeterminationtheory.org/intrinsic-motivation-inventory/. Accessed 8 February 2021.
[32] R.M. Ryan, E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, Am. Psychol. 55 (2000) 68–78. doi:10.1037/0003-066X.55.1.68.
[33] D. Stockemer, Quantitative Methods for the Social Sciences. Springer International Publishing, Cham, 2019.
[34] Jabberwocky Development Group. SUS - A quick and dirty usability scale.
[35] J. Hedderich, L. Sachs, Angewandte Statistik: Methodensammlung mit R, 15th edn. Springer Spektrum, Berlin, Heidelberg, 2016.