Product Safety and Quality Engineering

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StartPlay 2023 – Proceedings of the 2nd Interdisciplinary Conference on Gamification and Innovation

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Foreword

In the ever-evolving landscape of technology and human interaction, the integration of gamification principles into various domains has emerged as a transformative force. The StartPlay conference serves as a nexus for the exchange of creative ideas, new research, and innovative applications that harness the power of gamification to drive creativity, engagement, and problem-solving.

The premise of gamification lies in its ability to leverage game elements and design principles to captivate, motivate, and inspire individuals. As we delve into the diverse sessions and presentations within this conference, we aim to unravel the intricate ways in which gamification not only enhances user experiences but also catalyzes innovative thinking across fields such as education, business, health, and beyond.

The contributions presented in these proceedings represent the collective efforts of researchers and practitioners who have dedicated themselves to unraveling the transformative potential of gamification. From theoretical frameworks to practical implementations, the insights shared in this volume reflects the multidisciplinary nature of our exploration.

As we navigate the realms of game design, behavioral psychology, and technology, we invite you to continue the insights that unfold within these pages. The ideas presented here not only underscore the current state of gamification and innovation but also serve as beacons guiding us towards future possibilities and advancements.

Vorwort

In der sich ständig weiterentwickelnden Landschaft von Technologie und menschlicher Interaktion hat sich die Integration von Gamification in verschiedenen Bereichen als transformative Kraft erwiesen. Die StartPlay-Konferenz dient als Knotenpunkt für den Austausch innovativer Ideen, richtungsweisender Forschung und neuer Anwendungen, um Kreativität, Engagement und Problemlösungen mit Hilfe von Gamification zu fördern.

Die grundlegende Prämisse von Gamification liegt in ihrer Fähigkeit, Spielelemente und Designprinzipien zu nutzen, um Menschen zu motivieren und zu inspirieren. In den Präsentationen dieser Konferenz wollen wir die komplexen Wege aufzeigen, auf denen Gamification nicht nur das Benutzendenerlebnis verbessert, sondern auch innovatives Denken in Bereichen wie Bildung, Wirtschaft, Gesundheit und darüber hinaus anregt.

Die in diesem Tagungsband vorgestellten Beiträge repräsentieren die kollektiven Bemühungen von Forschenden und Praktizierenden, die sich der Untersuchung des transformativen Potenzials von Gamification gewidmet haben. Vom theoretischen Rahmen bis zur praktischen Umsetzung spiegelt die Bandbreite der in diesem Band geteilten Erkenntnisse die multidisziplinäre Natur unserer Forschung wider.

Während wir uns in den Bereichen Spieldesign, Verhaltenspsychologie und Technologie bewegen, laden wir Sie ein, die hier präsentierten wissenschaftlichen Erkenntnisse weiterzudenken. Die folgend vorgestellten Ideen unterstreichen nicht nur den aktuellen Stand von Gamification und Innovation, sondern dienen uns auch als Wegweiser für zukünftige Möglichkeiten und Fortschritte.

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Gamified feedback elements in assembly environments – workplace setup and planned user study

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- **Abstract**

Gamification elements are seen as a viable possibility to increase work and learning outputs as well as to boost engagement. While there exists a broad range of experiences in the educational area, gamified applications, as well as user studies in manual work contexts, remain rare. Therefore, it is unclear how gamification elements can impact employees' work execution. This work includes gamified feedback elements in an assistance system for industrial assembly tasks. A study design is presented, which will be used to compare the effects of gamified feedback elements during a routine assembly procedure of a handgrip.

- **Keywords**

Industrial Gamification, Assistance Systems, Feedback Elements

1 Introduction

Gamification, the usage of game elements in non-gaming contexts, is seen as a promising approach to increase user engagement throughout a variety of tasks [1,2]. While gamified applications are already very present in educational scenarios, work environments are also getting more and more equipped with gamified applications [3,4].

A special case of gamified work environments are manual assembly stations. In contrast to pure computer-based work environments which allow a direct inclusion of gamification elements, manufacturing environments require digitization efforts before gamification can be applied [5,6]. Thus, viable manufacturing systems for gamification should be equipped with some kind of assistance system capable of evaluating user interactions and presenting work instructions [7].

Although some gamified applications for manual work exist, it is still unclear how specific gamification elements impact the operators. In this work, a standard assistance system for assembly tasks is equipped with different types of gamified feedback elements. Instead of only showing a progress bar, different animations and sounds are included to provide individual operator feedback. For the analysis, a user study focusing on work performance, user engagement, and system usability is designed. By comparing two experimental groups – standard assembly vs. gamified assembly – the planned study should evaluate if the additional effort of including gamified elements in assistance systems for routine assembly procedures could benefit its users and the companies in terms of a more pleasant work design and thus increased engagement.

2 Literature review

Here, combining assistance systems for industrial assembly tasks with gamified feedback elements is targeted. To this end, existing research on gamification in manufacturing work is reviewed.

1.1 Gamified assistance systems

A huge variety of assistance systems already exist in the industry. They are used to display just-in-time instructions directly in working areas and are also capable of detecting user interactions for evaluation purposes. Also, work-integrated learning processes can be aimed at using such systems. Current trends focus on human factors to adjust the assistance systems to individual user needs. Gamification elements are seen as one possibility to fulfill these goals [8].

In logistics, operators are often equipped with Augmented Reality (AR) glasses which support and verify picking procedures [9]. Thus, gamification elements can be displayed directly in the users' field of visions. In assembly, in-situ projections can be used to present work instructions without impeding the operators. Nguyen and Meixner [10] applied a point system in combination with an additional support feature called "signposting" on an assembly training. In their study with 22 participants, no significant differences were found between the two testing groups. Korn et al. [11] included a Tetris game in a traditional assembly task setting. In their Tetris application, the brick movement speed was derived from previous assembly times. In their study, the production speed increased using gamification elements, however, error rates also went up.

1.2 Gamified feedback elements

Different game mechanics can be used to achieve the desired game dynamics and, thus, create player engagement [12]. In this work, visual feedback elements are focused which should highlight work achievements and promote constant productivity. Also, they should provide a clear goal to the users to achieve high performance and limit task performance variability [14].

Typical feedback approaches are points, badges, and leaderboards [13]. Hamari [14] analyzed the effects of badges on user engagement in a peer-to-peer trading service. In his field experiment, users exposed to the gamified application had a higher activity. However, a careful design and monitoring is required to prevent negative outcomes. Another feedback approach is to highlight achievements through visual graphs and animations. Krath et at. [2] recognized, based on the self-determination theory – a theory explaining human needs and motivations [15] –, and flow theory – a theory of optimal experience [16] – among others, that immediate feedback can be used as a guide to achieve the intended behavioral outcomes. In addition to visual feedback, the influence of audiovisual feedback was also investigated in detail. Bräuer et al. [20] discovered that both motivation and performance can be positively influenced.

Regarding the relationship of motivation and gamification, a recent study shows that interactions with achievement- and social-related features were positively associated with all dimensions of intrinsic need satisfaction. However, the interaction with immersions was associated only with fulfilling the need for autonomy. Thus, achievement-related features appear to have a greater influence on intrinsic need satisfaction [17].

In addition to motivational factors, the gamification strategy of the present study makes use of the concept of flow experience – a common theoretical basis of gamification [2, 18]. Flow describes the positive state of complete absorption in an activity that is perceived as optimally demanding [16]. Since flow is a pleasant experience and also has positive consequences, for example regarding well-being and performance [19], it is suggested to foster flow-promoting conditions at work. As summarized by Peifer and Wolters [19], various flow-promoting factors are already known from prior research. In addition to the feedback from the task described above, these include clear goals of a task, task significance, the use of a variety of skills, and a balance between the demands of a task and the skills required to perform it. Through gamification elements, these flow-promoting factors can be implemented aiming at a positive experience and increased performance of the participants when working in the gamified assembly context. In line with Liu et al. [18], we strive for a *meaningful engagement* characterized by positive effects of gamification on the level of well-being as well as performance.

Hypotheses

This work focuses on productivity, usability, and motivational outcomes of the gamification approach, that is intended to foster performance and flow experience. Based on the theoretical basis of the implemented gamification elements and the findings from motivation and flow research, we assume that gamification has different effects in the manufacturing context. The application of the gamification elements in an experimental context allows us to assume the following hypotheses: For the analysis, a significance level $\alpha=0.05$ is chosen.

Hypothesis 1: Participants of the Gamified-Group conduct the assembly routines faster than the Non-Gamified-Group.

Hypothesis 2: Participants of the Gamified-Group are more engaged in the task than participants of the Non-Gamified-Group.

Hypothesis 3: Participants of the Gamified-Group find the system more useful than participants of the Non-Gamified-Group.

3 Methodology

3.1 Gamified assistance system concept and implementation

This work includes gamified feedback elements in an industry-typical assistance system. It is based upon previous work regarding gamified assistance systems [5,7,21]. The assistance system displays situation-dependent work instructions and detects user interactions. The work sequence consists of 20 work steps in which parts must be mounted or clipped to form an industrial handgrip of the company Item Industrietechnik GmbH. One tool, a screwdriver, is required for the assembly execution. First, the side parts of the handgrip are premounted twice and placed in a storage box. Afterward, these side parts are attached to the main profile, and the covers are placed over the screws. In order to reduce the assembly complexity and simplify the small parts handling, a workpiece holder is used. The workpiece holder consists of 3D-printed parts, which limit the mounting options. The assembly device prevents faulty operations by using the hard Poka-Yoke principle hindering incorrect insertions of components through molds. In addition, the soft Poka-Yoke principle is applied. If an incorrect operation is performed, this is indicated to the user by notifications in the UI, by error sounds or light signals [21].

User interface

The user interface (UI) shows instructions on the work desk (Figure 1). The instructions include in-situ projections which indicate placement positions, 3D models of the complete handgrip, and additional mounting information. The implemented progress indicator shows the total number of work steps to be performed and accomplished. This element is considered separately from the gamified components, since this type of progress bar is usually found in many applications and assistance systems where the gamification approach is not primarily pursued.

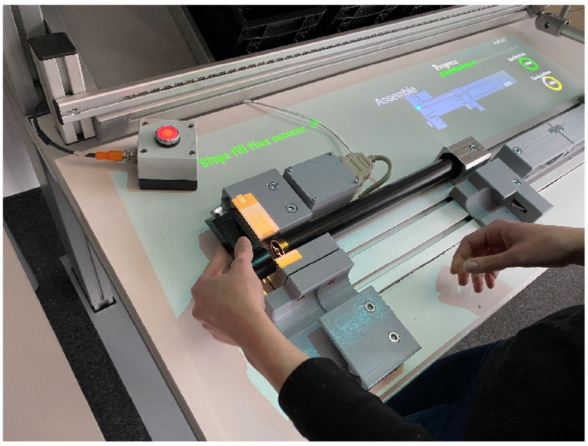

Figure 1: In-situ projections for the handgrip placement (orange) and the 3D-model of the handgrip (blue) and the workpiece holder (grey). Also, the progress bar and the username are shown.

Gamification strategy

In this work, the gamified feedback elements expand the traditional UI. A pre-test showed that the work routine does not include a high error probability. Therefore, the fulfillment of time requirements is focused on as a relevant performance measure. The production times of 10 trained participants who conducted the assembly five times are used as a baseline to determine default times. Different audiovisual feedback elements are triggered (Figure 2) when completing assembly steps. A combination of immediately occurring rewards [22] and rewards which are triggered for repeated requirements fulfillment is selected: Circular progress bars for time and quality fulfillment; congratulatory messages if a work step's time and quality requirements are met; small, animated star explosion at the progress bar when finishing a work step that are accompanied by sound effects; random counter, which reduces its number each time the user subsequently finishes a work sequence on time; animated eruption with visual and sound effects for subsequent timely actions when the counter is finished; green firework animations when keeping the time performance above 90% for the last four production steps; confetti or star animations when finishing a complete handgrip and jingles or sounds of applause to close the assembly.

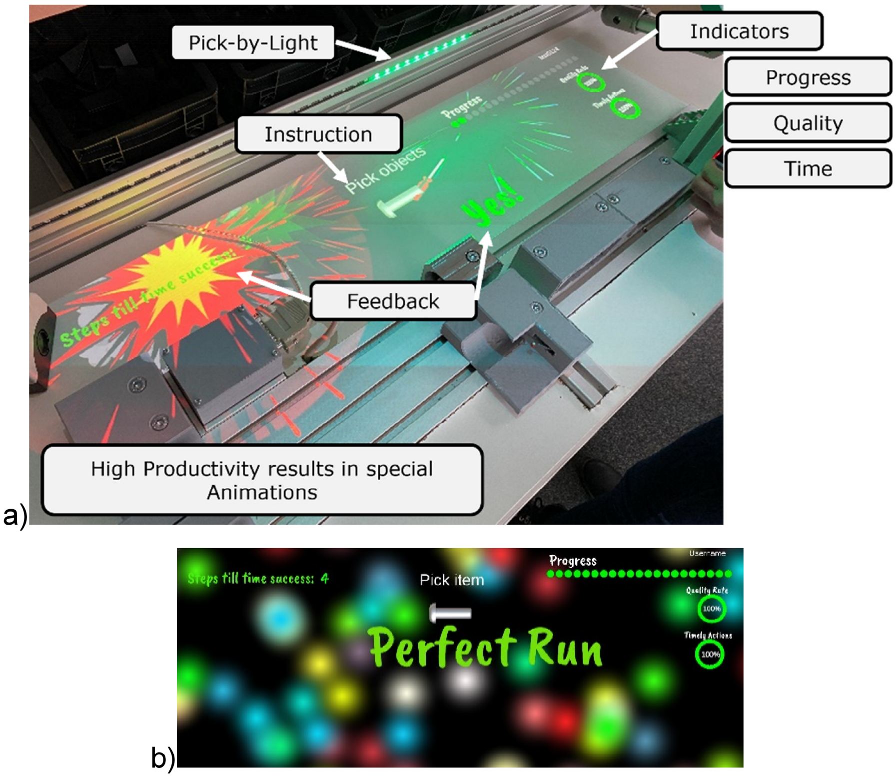

Figure 2: Examples of gamified feedback elements a) as feedback to a correct and fast action during the assembly process and b) when ending the assembly of a handgrip.

3.2 Study design

The user study is implemented as a joint project of the mechatronics engineers of the FH Aachen University of Applied Sciences and the work psychologists of the University of Lübeck. The study participants are divided randomly into two groups that differ in their UI designs. The Non-Gamified-

Group receives the standard UI, including work instructions and the progress bar as usual in assembly work. The Gamified-Group additionally receives the gamified feedback elements.

For the study, the previously described AR-supported manual workstation is used. Students of the FH Aachen and the University of Lübeck with varying backgrounds (mechatronics and industrial engineering, psychology, and media informatics) are targeted as participants. Study participation is rewarded in the study program for the selected student groups.

In the present work-in-progress paper, we focus on some specific aspects of the study design, and describe them in more detail in this section. However, more variables are assessed and a second paper is currently in preparation. We therefore do not discuss these contents further in the present study. Thus, in the flow chart (Figure 3), there are aspects that will not be further considered in this paper.

During the assembly, the time of all user actions is collected and indicators extracted: Production times per user and run; total production times per user; average production times per test group. A pre-test showed that the Poka-Yoke workpiece holder successfully prevents wrong executions so that usually no errors can occur. Therefore, error rates are not included.

For all participants, demographical data regarding age, gender, study area, previous technical experiences, and manual skills are assessed. After the assembly, different variables are assessed, among others assembly performance. Additionally, the Gamified-Groups' perceptions of the gamification elements are captured. Therefore, the participants are asked if they find the elements motivating, helpful, comfortable, or distracting.

The Intrinsic Motivation Inventory (IMI) [23-25] is selected to assess motivational aspects during the assembly task. For the IMI, the subscales "interest/enjoyment", "perceived competence", "effort/importance", "pressure/tension", "perceived choice", and "value/ usefulness" are included. In order to compare the usability of the gamified and non-gamified assistance system, the System Usability Scale (SUS) is applied [26].

The study starts with the participants' informed consent, a short questionnaire and an introduction to the assembly task providing information about the procedure. Afterward, a video is used to introduce the manual workstation functionalities to the participants. Next, the task is explained in detail by executing the assembly task once jointly at the workstation. During this initial assembly, no gamification elements are shown to avoid distracting the participants. This first execution allows the study supervisor to answer all questions and explain the screwdriver usage if required. After this introduction phase, the assembly cycles start. The participants assemble the handgrip five times while answering one question regarding their flow experience after each finished assembly (the study design regarding the flow experience is part of another work in progress). In the end, the participants receive the final questionnaire, including the IMI, SUS, and demographical data.

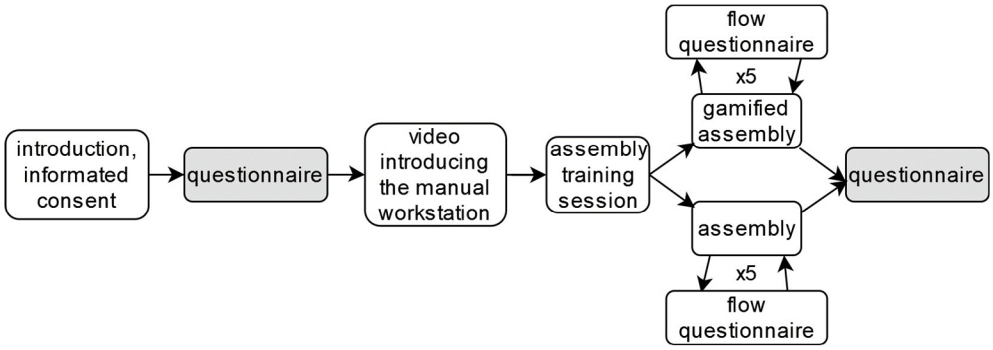

Figure 3: Flow chart of the experiment process.

4 Conclusion and outlook

This work includes gamified feedback elements in an assistance system for manual assembly tasks. The assistance system provides in-situ projections for work instructions and automatically evaluates the conducted user actions. Based on captured user data, different animations with sound are triggered in the workplace. The animations include round progress bars, star explosions, eruptions, and congratulatory messages. As the handgrip assembly does not include many error possibilities, time performance is focused on throughout the assembly process. In order to evaluate the impact of gamified feedback elements during assembly tasks, a user study is planned. The Non-Gamified-Group receives a standard UI, including work instructions and a progress bar. In contrast, the UI of the Gamified-Group is expanded with the gamified feedback elements. Combining the work data and questionnaires allows for a detailed analysis of the effects of gamified feedback elements on productivity, engagement, and system usability.

The study is a pilot study to systematically investigate gamified assembly work. The aim is to examine how gamification can have an effect on assembly work in addition to training processes. At the same time, the role of flow as an approach for designing gamification but also as an effect of gamification in the work context is to be evaluated. This work in progress paper thus describes only one aspect of a greater research plan. In this context, the design of gamification will also be critically examined. For example, the parallel use of visual and auditory gamification elements in the described first study should be reconsidered and controlled in future applications. Furthermore, an adaptive use of gamification should be aimed at in future applications in order to address the different preferences people show when experiencing flow. In an additional study, the findings will be used to optimize the implemented gamification strategies. While the present study investigates a short-term experimental setting, an application in a real production environment is envisioned in a long-term study to be conducted over a period of several months.

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6 Vita

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Learning by Questing - Integration von gamifizierten Quests zur Steigerung der Lernmotivation in der Hochschulbildung

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- **Abstract**

Gamification kann ein valides Mittel zur Steigerung der Motivation von Lernenden im Hochschulbereich sein. Dieses Paper stellt ein Tool vor, das Lehrenden ermöglicht, Übungsaufgaben als Quests in ein 2D-Rollenspiel zu integrieren, ohne über tiefgreifendes Wissen in der Software- oder Videospielentwicklung zu verfügen. Hierfür wurde eine Beschreibungssprache definiert, in der Aufgaben definiert werden können. Diese werden automatisch in verschiedene Spielszenarien umgewandelt, die von den Lernenden innerhalb des Spiels gelöst werden müssen. Darüber hinaus wird ein Ansatz beschrieben, bei dem Petri-Netze zur Definition von Aufgabenbeziehungen und alternativen Aufgabensequenzen genutzt werden, um den Ansatz des selbstgesteuerten Lernens zu verfolgen.

- **Keywords**

Gamification, Self-Paced Learning, Petri-Netze, DSL

1 Einleitung

Wir haben im Studiengang Informatik Module mit hohem Programmieranteil erfolgreich auf ein selbstgesteuertes Lernkonzept mit Gamification-Ansatz umgestellt. Die Studierenden erstellen in den Übungsaufgaben Code, um schrittweise in einem vorgegebenen Java-Framework ein eigenes 2D-Rollenspiel mit individuellen Spielelementen zu entwickeln. Laut Schreuders et al. [1] erhöht der Spielspaß die Motivation der Studierenden bei der Bearbeitung der Programmieraufgaben deutlich. Gleichzeitig wird der starken Heterogenität in Bezug auf Vorwissen Rechnung getragen (vgl. [2]). Dieses Paper erweitert den Game-based Learning-Ansatz und zeigt, wie Lehrende selbst Aufgaben für ein 2D-Rollenspiel formulieren können. Dabei werden fachliche Aufgaben als Quests im Spiel repräsentiert. Studierende anderer Fachrichtungen müssen keinen Quellcode schreiben, sondern lösen die vorgegebenen Aufgaben durch Spielen.

Ähnliche Projekte mit dem Ziel, Spiele zum Lernen im (Hoch-)schulkosmos einzusetzen, fokussieren sich auf modul- oder fachbereichspezifische Aufgabentypen [3]–[5]. Dabei konnte eine erhöhte Motivation der Lernenden durch das spielerische Lernen festgestellt werden; dieses Projekt geht darüber hinaus und setzt eine fachübergreifende Toolchain zur Gamifizierung von Übungsaufgaben um. Dafür wird das Framework so erweitert, dass mithilfe einer Beschreibungssprache Aufgaben in ein Spiel integriert werden können.

Die Lösungen und Lösungswege im Spiel werden über die im Framework implementierten Mechanismen bewertet. Analog zu den Ideen in Schreuders et al. [1] kann ein Akteur im Spiel diverse Belohnungen durch Lösen verschiedener Aufgaben(-typen) sammeln.

2 Vergleichbare Arbeiten

In der Lehre wurden bereits einige Erfahrungen zum Thema Gamification gesammelt. So haben Coller et al. [3] ein Rennspiel für das Modul Maschinenbau entwickelt, bei dem mit manuellem Schalten Bestzeiten gefahren werden mussten. Um möglichst gute Zeiten zu erreichen, musste der optimale Schaltpunkt getroffen werden. Um den optimalen Schaltpunkt zu finden, mussten Studierende die in der Vorlesung gelehrten Techniken anwenden. Die Ergebnisse deuten darauf hin, dass die Studierenden eine höhere intellektuelle Intensität, intrinsische Motivation und insgesamt mehr Engagement erfahren, wenn sie mit dem Rennspiel im Vergleich zu traditionellen Methoden für Hausaufgaben und Unterricht im Bereich Maschinenbau arbeiten.

Zum Lehren von UML-Modellierung wurde von Jurgelaitis et al. [4] ein Moodle-Kurs entwickelt, in dem Studierenden aufgeteilt in mehrere freischaltbare Level die Modellierung verschiedener UML-Diagrammtypen lernen. Weitere Features des Kurses sind Rewards, Leaderboards und Trading. Die Evaluation hat gezeigt, dass die Motivation der Studierenden stark gesteigert werden konnte. Eine geplante Erweiterung ist die automatische Validierung der eingereichten UML-Diagramme. In unserem Fall können die Aufgaben so designt werden, dass sie automatisch bewertet werden. Außerdem können eigene Bewertungsfunktionen implementiert werden.

Zwar nutzen beide genannten Arbeiten Gamification, um Lerninhalte eines konkreten Themengebiets aufzubereiten. Die erzeugten Artefakte eignen sich ohne größere Anpassungen jedoch nicht für einen Themengebiets-übergreifenden Einsatz. Das in diesem Paper vorgestellte Projekt ermöglicht das Erstellen von Übungsaufgaben aus verschiedenen Themengebieten.

Für Sustainable Entrepreneurship Education wurde von Frentz et al. [5] ein Escape Room entwickelt. Der Escape Room wurde als E-Book umgesetzt, in dem Texte, Bilder und Videos integriert sind. Quizze werden als Online-Tools über Links eingebunden, über die Studierende Codes zum Freischalten weiterer Inhalte erhalten. Die Autoren haben erkannt, dass ein E-Book Grenzen aufweist, da es nicht für diesen Einsatz konzipiert wurde. So kann zum Beispiel das Überspringen von Aufgaben nicht verhindert werden. Unsere Anwendung nutzt daher zur Kontrolle des Lernflusses ein Petri-Netz, mit dem der Aufgabenverlauf genau gesteuert werden kann.

3 Definition von Aufgaben mit einer Domain Specific Language (DSL)

Bei der Umsetzung einer Aufgabe als Quest ergeben sich verschiedene Herausforderungen. Zum einen sollen die fachbezogenen Inhalte im Vordergrund stehen und nicht die Spielmechaniken. Zum anderen soll das Lösen der Aufgabe Spaß machen und dadurch die Lernenden motivieren. Außerdem sollen auch Lehrende ohne Kenntnisse von Software- oder Videospieleentwicklung auf einfache Weise eine Aufgabe formulieren können, die automatisch in das Spiel integriert wird.

Mithilfe der eigenen Beschreibungssprache (DSL) und einer Toolchain zur Umwandlung von Aufgaben in Quests sollen Lehrende bei der Integration ihrer Aufgaben unterstützt werden. Lehrende formulieren Aufgaben in der DSL, die dann in das Spiel geladen werden. Für eine minimale Aufgabendefinition muss nur der Aufgabentyp ausgewählt werden und die Aufgabenstellung sowie Lösung angegeben werden. Über die DSL-Toolchain wird die formulierte Aufgabe in eine konkrete Quest übersetzt. Angeregt durch das Konzept von Lemoine et al. [6] kann dabei eine Aufgabe automatisiert auf mehrere vordefinierte Szenarien (konkrete Spielsituationen) abgebildet werden.

Die Definitionen der Szenarien sind abhängig vom Aufgabentyp und werden ebenfalls in der DSL formuliert. Einige Szenario-Definitionen werden in einer Standardbibliothek zusammen mit der DSL ausgeliefert. Dazu gehören auch einige vordefinierte Bewertungsfunktionen zur Auswertung der Lösungen, die die Eingaben der Lernenden analysieren und bewerten. Es ist auch möglich eigene Bewertungsfunktionen in der DSL zu definieren.

```
replacement_task chemie {
  description: "Führen Sie Fotosynthese durch!"
  initial_element_set: {10x"C", 10x"O2", 10x"H2O"}
  elements: {
    n1: ("C", "O2"),
    n2: {"CO2"},
    n3: {6x"CO2", 6x"H2O"},
    n4: {"C6H12O6", "6O2"}
  },
  rules: {
    r1: n1 -> n2,
    r2: n3 -> n4
  },
  answer_configuration: ["C6H12O6", "6O2"],
}
```

Abbildung 1: Beispiel für eine Ersetzen-Aufgabe zum Thema Fotosynthese in der DSL. In “initial_element_set” werden die initial verfügbaren Elemente definiert. Über die in “rules” definierten Regeln können die Elementkombinationen aus “elements” zu neuen Elementen kombiniert werden. Eine Aufgabe ist korrekt gelöst, wenn die Antwort mit dem Ergebnis in “answer_configuration” übereinstimmt.

Bei der Auswahl der umzusetzenden Aufgabentypen wurde darauf geachtet, dass die Aufgabentypen unterschiedliche Aufgaben in verschiedenen Fachbereichen ermöglichen. Die Aufgabentypen sind Single-Choice, Multiple-Choice, Lückentext, Ersetzen und Zuordnen. Bei Ersetzen muss aus einer Gesamtmenge aus l Elementen eine Menge mit m Elementen durch eine zweite Menge mit n Elementen ersetzt werden. Bei Zuordnen müssen Elemente aus einer Menge A den Elementen aus einer anderen Menge B zugeordnet werden. Fachspezifische Aufgabentypen wurden nicht umgesetzt. Für die verschiedenen Aufgabentypen werden verschiedene Szenarien umgesetzt, um die Aufgaben abwechslungsreich im Spiel zu integrieren, beispielsweise das Aufsammeln von bestimmten im Spiel verstreuten Items oder durch das Ablegen bestimmter Gegenstände in eine Kiste.

In diesem Fallbeispiel wird eine Aufgabe aus dem Bereich Chemie formuliert und in das Spiel integriert (Siehe Abb. 1). Die Lernenden müssen dabei das Reaktionsschema von Fotosynthese anwenden, indem sie schrittweise die definierten Regeln anwenden. Jede Aufgabe besitzt einen Namen, damit sie an anderen Stellen der DSL, etwa in anderen oder in verschachtelten Aufgabendefinitionen referenziert werden kann. Neben der Angabe der korrekten Antwort über „answer_configuration“ können auch die Lösungsschritte definiert werden über „answer_sequence“.

Diese Aufgabe wird im Spiel als Crafting-Szenario (Siehe Abb. 2) repräsentiert. Dabei werden die verschiedenen Elemente der Ausgangsmenge als Items zum Aufsammeln im Spiellevel verteilt. Diese Items können die Lernenden an einem “Zauberkessel” miteinander kombinieren und erhalten entsprechend den formulierten Regeln neue Items. Im Fallbeispiel würden die Items die chemischen Verkettungen aus der Aufgabenstellung repräsentieren. Ziel der Lernenden ist es, schrittweise die richtigen Items im Zauberkessel zu kombinieren, bis die Aufgabenstellung gelöst ist. Um die Aufgabe etwas schwerer zu gestalten, kann man zusätzliche Items und Regeln formulieren, die nicht für die korrekte Lösung genutzt werden sollen.

Abbildung 2: Umsetzung des Fallbeispiels im Dungeon. Studierende müssen die Zutaten in der richtigen Reihenfolge per Drag and Drop aus dem Inventar auf den Zauberkessel ziehen.

4 Steuerung des Aufgabenverlaufs mit Petri-Netzen

Zur Modellierung von Beziehungen zwischen (Teil-)Aufgaben und zur Steuerung der Reihenfolge der Bearbeitung von Aufgaben wird ein auf Petri-Netzen basierender Modellierungsansatz untersucht. Darüber können Aufgabensequenzen und alternative Pfade durch ein Level definiert werden und es können Aufgaben(-teile) als optional markiert werden. Studierende können so eigenständig die nächsten Aufgaben zur Bearbeitung auswählen.

In der DSL können Lehrende Beziehungen zwischen mehreren (Teil-)Aufgaben definieren:

- Reihenfolge: Es können (Teil-)Aufgaben definiert werden, welche zuerst bearbeitet werden müssen, um andere Aufgaben(-teile) zur Bearbeitung freizuschalten. Die Folgeaufgaben können auch bedingt durch die Qualität der Lösung der Voraufgaben definiert werden.
- Dynamik: Abhängig von den Ergebnissen der Bewertung einer Aufgabe kann definiert werden, welche Folgeaufgaben nach der Bearbeitung einer Aufgabe freigeschaltet werden. Nach einer schlecht bearbeiteten Aufgabe kann eine einfachere Aufgabe aktiviert werden oder bei einer guten Lösung eine anspruchsvollere Aufgabe zur Bearbeitung freigeschaltet werden.
- Optionalität: Für eine Aufgabe kann es mehrere Teilaufgaben geben, welche entweder vollständig oder teilweise (2 von 3) gelöst werden müssen. Auch optionale Teilaufgaben können formuliert werden.

Diese Aufgabenbeziehungen können beliebig miteinander kombiniert werden. Eine Teilaufgabe könnte wiederum selbst aus Teilaufgaben bestehen etc.

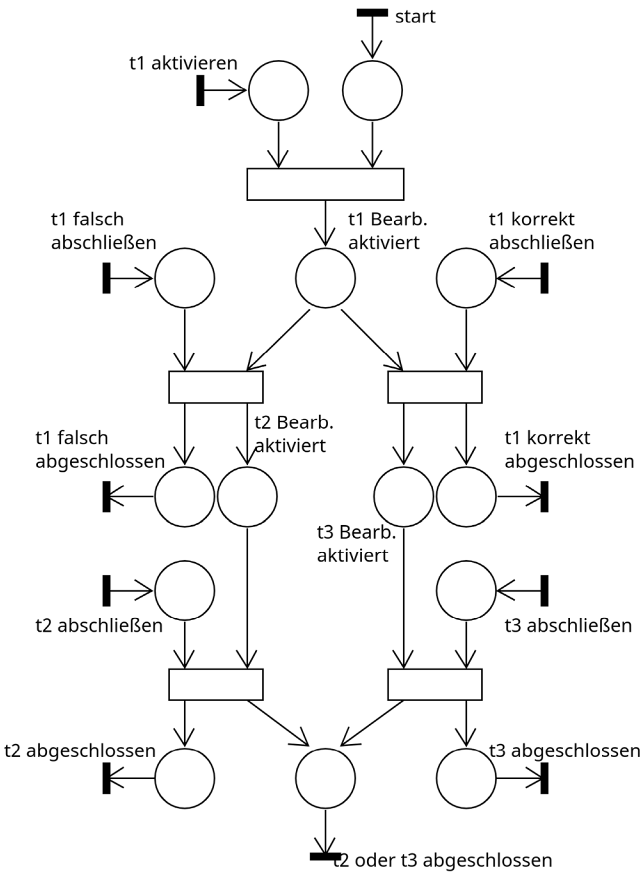

Abbildung 3: Petri-Netz mit bedingter Aufgabensequenz bestehend aus den drei Teilaufgaben t1, t2 und t3. Dabei muss zunächst Teilaufgabe t1 komplett bearbeitet sein, bevor die anderen beiden Teilaufgaben zur

Bearbeitung freigegeben werden. Zum Abschluss dieser Aufgabe müssen die Lernenden entweder Teilaufgabe t2 oder Teilaufgabe t3 lösen.

Diese per DSL-Eingabe definierten Aufgabebeziehungen werden in ein Petri-Netz übersetzt, welches zur Spiellaufzeit den Zustand aller Aufgaben überwacht und basierend auf den bearbeiteten Aufgaben weitere Aufgaben zur Bearbeitung freischaltet. Ein Beispiel bestehend aus drei Teilaufgaben zeigt Abb. 3.

5 Grenzen und Ausblick

Das Projekt richtet sich an Lernende mit Interesse an Videospielen. Lernende mit wenig Interesse an Spielen werden nicht motiviert. Das Projekt versteht sich daher als Zusatz zu klassischen Übungsaufgaben. Ansätze zum Einsatz in Prüfungsszenarien wurden untersucht, jedoch muss bedacht werden, dass Studierende in Prüfungssituationen die begrenzte Zeit nicht mit dem Herumlaufen im Level oder dem Besiegen von Monstern verbringen sollten.

Bisher konnte das Projekt noch nicht evaluiert werden. Es soll jedoch eine Evaluierung mit Studierenden und Lehrenden umgesetzt werden. Dabei soll zum einen überprüft werden, ob das Projekt den Lernerfolg der Studierenden fördert als auch ob die DSL für Lehrende gut anwendbar ist und sich die gewünschten Aufgabentypen damit abbilden lassen.

Um den Lernenden eine Hilfestellung zu bieten, falls diese bei der Lösung einer Aufgabe nicht weiterkommen, kann ein dynamisches Hilfesystem implementiert werden. Mithilfe der Petri-Netze könnte dieses den aktuellen Bearbeitungszustand analysieren und gezielte Hilfestellung durch vorher definierte Hilfetexte anbieten.

Aktuell ist das Projekt auf wenige Aufgabentypen begrenzt, was es unter Umständen nicht erlaubt einige analoge Aufgabentypen in das Spiel zu laden.

Nach Bartle [7] gibt es verschiedene Spielertypen. Eine Erweiterung des Spiels um eine Analyse des Spielverhaltens, um den Spielertypen zu bestimmten, würde es erlauben, die Szenarien gezielt nach dem Spielertypen auszuwählen und so den Spaßfaktor für die Lernenden zu erhöhen.

Das QTI-Format [8] ist ein standardisiertes Format, um Aufgaben zu speichern, welches in LMS wie beispielsweise ILIAS eingesetzt wird. Die Entwicklung eines Tools zur Übertragung von QTI-Aufgaben in die DSL würde die schnelle und bequeme Integration bereits bestehender Aufgaben ermöglichen. Dadurch würde die Einstiegshürde gesenkt.

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7 Vita

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Exploring the metaverse as a catalyst for human-AI collaboration

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Abstract

Artificial intelligence (AI) holds significant potential for transforming human value creation. One specific area where AI is having an impact is collaborative robots, which are increasingly being utilized in industry to support human workers. However, harnessing the full potential of AI is hindered by human factors, including resistance to change, low trust in AI, and a lack of effective approaches for human-AI collaboration. Simultaneously, the metaverse offers unexplored possibilities to support human-AI teaming. Therefore, we believe that it may serve as a catalyst for overcoming current barriers and improving human-AI cooperation. We propose using perspective switching in immersive virtual games to induce empathy and reduce existing biases between humans and intelligent machines. Thus, next to a prototype, we present the setup and initial results of an experiment that strives to investigate the suitability of perspective switching to boost trust toward AI-powered robots.

- **Keywords**

Human-Robot Interaction, Collaborative Robots, Metaverse, Perspective Switching

1 Introduction

Artificial intelligence (AI) can augment labor-intensive manufacturing tasks [1] by enabling promising applications, such as inline quality inspection and automatic detection of defects and non-conformities [2]. Experts agree we will also witness a rise in the demand for AI-powered collaborative robots (cobots) in industrial settings [3] as these solutions tend to be cost-effective, easy to implement, and (re)program. Also, cobots may be key to automating repetitive processes and can even learn from the interaction with users [3]. Evidently, this makes cobots an interesting candidate for supporting workers in manufacturing tasks ranging from material handling and removal, machine tending to final quality inspection. With the increasing proliferation of AI-powered cobots, the development of suitable concepts for human-AI collaboration is gaining importance. However, knowledge and research concerning future human-AI interactions are scarce. Several obstacles currently prevent the adoption and more widespread implementation of AI-powered robotic systems. Emotional barriers arise, for example, when human users perceive these systems as opaque machines as they cannot comprehend the logic behind decision-making processes [4]. Emotional barriers are connected to fears and negative stigmas surrounding the design, interaction, reliability, and the shifting role of the ever more intelligent partner in human-machine teams [5]. Often, a lack of trust prevents fruitful cooperation between humans and AI-powered systems and undermines the emerging roles of cobots in the manufacturing industry. Little is known about mechanisms that facilitate the creation of trust and the altering of the perception towards robotic assistance, which emphasizes that novel approaches to increase trust in AI-powered robots are needed. Simultaneously, we witness an increased interest of researchers and practitioners in the 'metaverse' [6]. The virtual extension of the physical world enables not only seamless communication between human users embodied in avatars or holograms in real time but also dynamic interactions with digital artifacts [7]. This gives rise to numerous exciting novel interaction scenarios that were formerly impossible, which may disrupt how we engage with others and technology [8]. Sandbox video game platforms like Roblox, Fortnite, and Minecraft create immersive virtual realities and facilitate interactions between human players as well as between human players and non-player characters (NPCs) [9]. Given these seamless interactions with NPCs, the metaverse may be a major catalyst for future human-AI collaboration [10]. We strive to investigate the suitability of perspective switching to increase trust toward AI-powered robotic interaction partners. Our research transfers this concept mainly studied in human psychology and applies it to human-AI teaming. There is ample evidence in human psychology that perspective switching can help to induce empathy on a cognitive and emotional level and reduce existing biases [11]. The design pattern perspective switching is also frequently employed in video games to improve the cooperation between human players and NPCs that humans do not directly control [12]. Perspective switching can be a powerful means to make players sympathize with NPCs and be deliberately applied to elicit feelings towards NPCs. So-called spectator modes have become indispensable in gaming, especially in multiplayer video games [13]. Typically, one player can watch other players and view equipment and movements but cannot actively engage in the game. Harnessing the stimulus introduced by the swap of views may create cognitive and emotional responses while allowing players to learn from their past actions and their counterparts [14]. Little is known, however, about the impact of perspective switching on the willingness to engage and cooperate with robots in real-world settings and within virtual realities. Therefore, our research question is as follows:

How does perspective switching with an AI-powered cobot in a manufacturing metaverse game affect human perceptions regarding reliability, functionality, helpfulness, and ultimately trust toward the robot?

2 Hypotheses (H)

This study aims to assess the difference in trust levels towards an AI-powered collaborative robot, after and before a perspective switching intervention. To measure the subjective perception of trust, we employed McKnight et al.'s construct of trust in specific technology [15], which encompasses the subdimensions of reliability, functionality, and helpfulness. The variables attitude and behavioral intention stem from the technology acceptance model (TAM) developed by Davis [16]. The items were adapted to fit our specific use case.

The belief in the robot's **functionality** refers to whether the user expects the technology to have the capability to perform a desired task [15]. Perspective-taking is a means to improve the understanding of the target person. By putting themselves in the robot's shoes, players are expected to understand better why the robot performs its tasks in certain ways. This is enabled by an increased knowledge regarding the robot's perception of its environment, which also facilitates the player to grasp how algorithmic decisions are made. This is especially important in this context as research provides evidence that people tend to mistrust algorithmic decisions [17]. Perspective switching was shown to result in a heightened concern and increases prosocial behaviors [18]. Several studies illustrate the positive impact of perspective switching on racial bias, stances towards immigration, and intergroup relations [19]. Previous research in human-robot interaction (HRI) emphasizes that with sufficient social cues and human-like features, people tend to attribute objects – including robots – human qualities and mental states [20]. Therefore, we expect that perspective-taking with a cobot elicits comparable feelings and increases the perceived competence and functionality of the robot (**H1**).

Helpfulness refers to the belief that a specific technology will provide appropriate, effective, and responsive user help [15]. Perspective-taking helps people to leave their egocentric perspective and enables them to anticipate the behavior and reactions of others [21]. There is evidence highlighting that any perspective switching (e.g., traditional, desktop, or via virtual reality) can evoke and boost empathy towards other parties [22]. People even tend to treat objects and machines as social actors and interact with them as if they were humans. Consequently, we assume that after the perspective switching exercise, the study participants will anthropomorphize the robot and perceive it more favorably. Players are thus expected to more easily attribute the robot the ability to show social benevolent behavior and to perceive the robot as a more responsive interaction partner [23]. Thus, we believe that perspective-taking leads to an increase in the perceived helpfulness of the robot (**H2**).

Reliability is the belief that the specific technology will consistently function properly [15]. This evaluation is often based on whether it operates continuously and responds predictably to inputs. In HRI, the perceived reliability indicates how much users would rely on the robot [24]. As the cobot will be unknown to the study participants, we assume this will initially translate into low ratings of its reliability. We argue, however, that the robot will be perceived as more reliable in the post-treatment survey because its behaviors and functions are scripted and executed automatically and predictably. Further, perspective switching has been shown to increase liking, closeness, and connections with the target [25]. The reason is that during perspective-taking, individuals see more of the self in the other and because individuals tend to have a very positive view of themselves [26]. It is thus a powerful means to improve social relationships. It can help to decrease stereotypes and prejudices about the target person and groups by transferring a positive self-concept to the other person and perceiving the target person as more self-like [27]. Given the cooperative nature of the task in our game and the plethora of design elements aimed at showcasing the dependability and trustworthiness of the robot agent, we are convinced that players will rate the reliability higher after the perspective switching intervention (**H3**).

3 Research Methodology

The study participants are randomly assigned to either the control or the experimental group. Only experimental group participants can perform a swap of perspectives with a cobot. After an onboarding session, key demographic data are collected. Next, participants are prompted to complete the first survey with five-point Likert scale questions. Then, the player starts the interactive game, which is set on a final assembly shopfloor of a manufacturing company. The use case revolves around the cooperation between a human player and a cobot worker. The mobile cobot with humanoid features and the human player are supposed to build vehicles and solve 3D puzzles jointly. The cobot works in the pre-assembly area, which is separated from the human's workstation by a conveyor belt. Players in the experimental group can witness the decision-making processes of the robot and catch an in-depth glimpse of its inner workings. By pressing a button displayed prominently on the screen, they instantly view the game from the cobot's perspective. They see how the robot perceives its environment with distinct sensors, processes information from different sources, recognizes patterns, executes tasks, and anticipates needs by interpreting moods and actions. After the intervention and 3D game experience (20 minutes), the players are prompted to complete the second survey.

The game was developed with the help of the Roblox video game engine in Roblox Studio. We ran an a priori power analysis in G*Power v3.1 [28] to calculate the minimum required sample size for a Mann-Whitney U test, considering an expected effect size of 0.5, an alpha error probability of 0.05, and a desired statistical power of 0.8. This resulted in a sample size of 106 participants required to detect a significant effect in the data reliably. We will analyze the collected ordinal data from the main survey with descriptive and inferential statistics in SPSS Statistics 28 and SmartPLS 4. We will perform a Mann-Whitney U test to test the differences between two groups on a single ordinal variable with no specific distribution [29]. Additionally, we may perform a Student's t-test depending on the data distribution.

4 Conclusion, Initial Results, and Outlook

Our study aims to identify how taking the perspective of a cobot in a metaverse manufacturing game affects the perception of its reliability, functionality, and helpfulness and ultimately evaluate its impact on trust and the intention to use the system in a manufacturing context. The experiment is based on a between-subject study design. The initial data collection phase took place from 2023/07/07 – 2023/07/09 during the Digital Festival in Nuremberg, resulting in promising preliminary results. A total of 31 participants completed the study, with 13 individuals randomly assigned to the experimental group and 18 participants allocated to the control group.

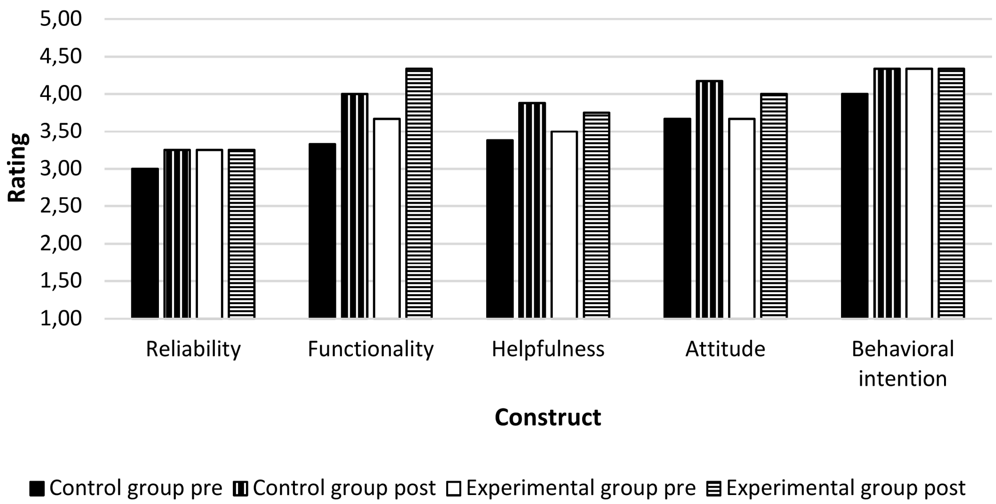

Figure 1: Median values of all measured constructs before and after the intervention.

As visible in Fig. 1, both groups exhibited a notable increase in the constructs functionality, helpfulness, and attitude. The experimental group obtained the highest median rating of approximately 4.45 after the perspective switching intervention. Contrary to our expectations and hypotheses, the measured values of behavioral intention and reliability were not or only slightly affected by the stimulus perspective switching, as evidenced by almost identical ratings prior to and after the intervention.

This work theoretically and practically contributes to the HRI community by providing intriguing pathways for designing future generations of industrial cobots and gauging the interactions with AI technologies in manufacturing. The main user study is expected to take place between July and December 2023.

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Gamification design enabling motivational self-regulation and cooperation

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- **Keywords**

Self-Regulation, Motivation, Flow, Enjoyment, Cooperation, Gamification Design

1 Extended Abstract

Gamification design is a tool that adds playful game elements to products and technology in various contexts. This stimulates users to execute specific behaviors in non-game contexts by creating a high user experience (UX). Gamification design has potential in Innovation Management and Marketing for making products more enjoyable and appealing [1, 2]. This can also enrich advertisings of products in online and offline shopping. Intrinsic and extrinsic game elements have been found to make products more attractive and add value, such as with storylines, social media, leaderboards or challenges [1, 3].

The effect of gamification design depends on the adaptation to a specific situation that motivates a positive UX in line with the users‘ goals while interacting with the product [2]. At the point of sale, gamification can induce a positive attitude towards a product and its advertisement and lead to higher buying intentions [1]. In addition, gamification design can support the interaction with websites, apps, or digital platforms that enable communication with friends, service personnel or other users [2, 3]. Gamification signals novelty and innovativeness of products and technologies [4].

Psychological theories on self-regulation describe the motivational processes that influence consumers to buy and use a product. Flow, intrinsic motivation and social comparisons are important for users to enjoy the communication with technologies and gain feedback [1, 3]. This supports self-regulation and goal-setting processes in applied contexts with effective gamification designs [2]. We outline practical examples, such as the gamification of self-regulation in cooperation and e-learning.

1.1 Cooperation versus competition in self-regulation

Cooperation can be induced by instructing people to consider themselves as part of a team that works towards common goals. This has been shown to enhance performance and creativity in work and learning environments [5, 6]. Gamification can be used to stimulate cooperation goals when people interact with others [7]. This is of particular importance in educational settings that aim to teach communication and social skills [8, 6]. Even in organizations, team work is more and more emphasized and many companies prefer an integrative or participative leadership style [6].

It would, therefore, be important to develop designs that encourage cooperation rather than competition between team members [5]. This can be implemented in a gamified design by embedding instructions and slogans highlighting cooperative goals toward other people by building a team and working together [2, 5, 7]. This also includes social feedback from other users, as in quizzes or crowdsourcing in digital environments with social comparisons and simulations. Assuring social involvement with others and providing support can also support users to cope with distractions and interruptions during task performance [9].

Challenges can be designed in a way as to bring out the best in each team member, instead of fighting each other [3, 5]. Cooperation and empathy could be valued by the feedback system and rewarded with bonuses and positive attention on social media. Focusing on team work with gamified designs could thus train integrative and inclusive problem-solving and participative decision making.

Besides cooperative games, there are also gamified functions available where users challenge each other, or compete and compare themselves on leaderboards [3]. The important question is whether inducing competition goals with game elements can be truly motivating and stimulating for users. An important finding was that for some people rankings were of high relevance, such as competing with others and striving for top positions, but for others this was not important [10]. Kruglanski and Mayseless [11] report that competition-oriented people may show a higher interest in social comparisons than people with less competitive traits. Therefore, competitive elements could be interesting mainly for competition-oriented consumers who strive to compete with others, for example by demonstrating their trophys on social media [3, 11].

In communication designs, it might thus be crucial to emphasize cooperation instead of competition goals since not everyone is competition-oriented [5, 11]. Many target groups strive for social connectedness and inclusion in groups and value communal goals. In particular, innovative products and technologies are oftentimes used to fulfill social goals to fit in with a group. Social comparisons and feedback can thus be employed in gamified designs to connect users to support each other and work towards a common goal [12]. This might also train and enable further social skills [8, 12].

1.2 Gamification design in e-learning

During times of digitalization, e-learning gains importance in educational and occupational settings. Students need to be motivated for self-regulated learning in homeschooling, and technology may support them. Educational self-regulation also gains importance for lifelong learning across the lifespan [8] and could be enriched by gamified designs.

Gamification is particularly useful to make learning materials more relevant in routine situations where users need stimulation. As a practical example, gamification can be employed in boring learning contexts to raise engagement [13]. Depending on their design, game elements can focus on learning and knowledge acquisition, but also on task performance. Goal-setting can be embedded within a digital platform and direct users' attention during e-learning. Feedback on their learning and performance can be more effective with gamified designs that enable continous self-regulation and monitoring of goal progress [8, 9].

Gamification designs are not as interactive as full games, but they have the advantage that they are easier to implement [14]. To foster educational self-regulation [8], digital platforms could display motivating pictures and slogans to users that lead to a positive emotion and UX [2]. Group work could be implemented in the classroom by creating a design that contains instructions for the framing of a cooperative group context [5].

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3 Vita

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Serious games and gamified apps in healthcare: an analysis of the application of regulatory, quality, and clinical validation frameworks

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- **Abstract**

Games and gamified applications have gained popularity in healthcare, but it is unclear if many are either effective or meet regulatory compliance requirements. This analysis investigates the evidence supporting the therapeutic claims of gamified health apps and their compliance with the Medical Device Regulation (MDR) in the EU. Among 530 identified applications, 143 were gamified health apps, with 19 (13.3%) qualifying as medical devices. Only 3 (15.8%) of certified apps provided evidence of quality and effectiveness. The remaining 16 apps (84.2%) lacked certification and evidence. Future research should focus on developing a quality framework for gamified applications, emphasizing efficacy studies and comparing them to traditional therapy methods. Compliance with regulatory requirements and evidence-based approaches are crucial for the successful market entry of individual gamified health applications in the medical field and for the overall success of the sector.

- **Keywords**

serious games, gamification, medical device regulation, regulatory compliance, scoping review

1 Introduction

In recent years, games and gamified applications have gained significance in various domains of society [1, 2]. They are not only utilized for entertainment but also serve various practical purposes in the form of serious games (SGs) and gamification. Such products are used in many fields, including healthcare, education, well-being, advertisement, cultural heritage, museums, and specific training (e.g., cybersecurity) [1, 3].

For products from the medical sector, however, special requirements apply. The legal and ethical context places particular demands on healthcare-related products regarding compulsory quality management frameworks for the development, release, audit, and clinical evidence of safety and efficacy. These demands also apply to serious games and gamified applications. In this paper, we examine whether the therapeutic claims of services are supported by evidence and whether they meet the required regulatory standards for approval.

2 Theoretical background

2.1 Serious games and gamification

SGs and gamification are two related concepts that attempt to utilize the engaging and motivating capabilities of games to achieve serious objectives [4, 5]. While the first term describes an "Interactive computer application, with or without significant hardware components, that has a challenging goal, is fun to play and engaging, incorporates some scoring mechanism, and supplies the user with skills, knowledge, or attitudes useful in reality [...]" [6], the latter is often defined as "the use of game design elements in non-game contexts" [5]. However, Werbach [7] shows that this definition is limited since not all implementations of such elements necessarily lead to a game-like experience. A more coherent definition by Sailer et al. defines gamification as the "[...] process of making activities in non-game contexts more game-like by using game design elements.[8]"

Serious games are therefore oriented towards games from the entertainment sector regarding visual presentation and control conventions and often have specific hardware requirements. They are used as training games for rehabilitation, educational games to teach knowledge or skills, e.g., about particular diseases, or games to treat specific conditions [4, 9]. In addition to knowledge transfer, the focus is often on behavior change [10].

Gamified applications use only aspects of games like points, badges, high scores, leaderboards, or storytelling to reach their goal [8]. This abstraction brings less financial effort for the development and fewer limitations, e.g., the necessity of specific hardware, when compared with SGs. The approach is best known in fitness apps [11, 12]. However, it has been recently adapted to other areas, such as nutrition, mental health, or the management of chronic conditions [12].

2.2 Healthcare-specific implications

SGs and gamification face similar challenges in the healthcare sector: these products must prove their effectiveness and efficiency in a world driven by evidence-based medicine. Available evidence supports that SGs improve patients' knowledge about their condition [13, 14], which can also be maintained over the long term [15]. Systematic reviews indicate a limited effect on the clinically important measure of behavioral change [10, 15] and no significant difference in clinical outcomes when comparing SGs with other forms of therapy [10]. In addition, the quality of some studies is limited [16]. However, certain studies focusing on specific diseases have demonstrated positive effects on behavior, such as improved therapy adherence and increased self-efficacy [17–19].

Systematic reviews on gamification present a diverse range of findings as well. In terms of behavioral impacts, a mixed picture emerges, with some studies reporting positive effects while others show negative or neutral outcomes [12, 20]. In some cases, gamification proves effective for specific diseases, while its impact is insignificant for others [21]. Additionally, there is a lack of qualitative study design, including the absence of randomized controlled trials (RCTs) [12, 20–22].

Furthermore, SGs and gamified applications are rarely compared to traditional learning methods, making it difficult to draw conclusions about their relative effectiveness. The few studies on the subject show inferiority in knowledge acquisition [23] or no differences between gamified and non-gamified interventions [24].

2.3 SGs and gamified applications as medical devices

Even though the overall efficacy of such approaches is being validated [22, 25], one crucial aspect has been neglected, which can be a significant obstacle to market introduction. Since many of SGs and gamified products in the medical field are therapeutic measures or have a therapy-modifying effect, they are medical devices (MDs) and would then fall under corresponding regulations in many countries, including the MDR in the EU [26]. Although many use cases are likely relatively low-risk, with corresponding lower requirements in approval processes, some other aspects of games and gamification could pose relevant risks, e.g., novel challenges in assessing changeable, situation-specific "interfaces" or difficult-to-assess psychological effects of a gamified approach. These challenges have become more significant with the introduction of tougher EU regulatory approval pathways in MDR. The app stores have an essential role in ensuring non-compliant apps do not enter the health market, as they are considered distributors and importers of the MD apps they make available [26]. From 2021, they must ensure these apps are approved, and correctly CE marked [27], but there is evidence that this critical public safety role is being carried out in a patchwork fashion.

3 Methods

3.1 Design

To investigate our hypotheses, we carried out a pilot screening and planning exercise for a scoping review using an existing database by Schmidt-Kraepelin et al. that contains the 530 most popular mHealth apps for iOS and Android systems in both major app stores, Apple App Store and the Google Play Store from 2018 [28]. We also used the definition of gamification used there, which has been previously published elsewhere [29]. All gamified applications were then assessed to determine whether they must be considered MDs in the EU and thus fall under MDR. Herein, we also provide an overview of which risk classification they would likely belong to.

The database is publicly available as part of the multimedia index of Schmidt-Kraepelin et al. on the JMIR mHealth and uHealth website [28]. The data was downloaded and imported into Microsoft Excel for Mac Version 16.62.

3.2 MDR classification process

The term "medical device" defines various instruments, software, implants, materials, and more that manufacturers create for specific medical purposes. These purposes include diagnosing, preventing, monitoring, predicting, treating, and alleviating diseases; addressing injuries or disabilities; investigating or modifying physiological processes; and providing information through in vitro examination of human specimens. MDs are divided into classes (Class I to Class III) depending on the risk assessment [26]. Referring to classification, we have applied the classification rules as stated in Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on MDs ANNEX VIII [26] and, for borderline cases, the Manual on borderline and classification under Regulations (EU) 2017/745 and 2017/746 - Version2 - December 2022 [30]. We also used, as a guide, the rationale set out in the previous EU borderline manual [31] and guidance set out by the UK regulator (the MHRA) when they were members of the EU [32]. The name and manufacturers of the products classified as MD was collected. Information on certifications and evidence was obtained from PubMed, manufacturers' websites, and the Google search engine.

4 Results

Of 530 applications in the database, 143 could be considered gamified. A detailed description of these applications was published elsewhere [28]. Of the 143 gamified health applications, 19 (13.3%) could be considered MDs. The highest-ranking application was *Ovia Pregnancy Tracker & Baby Countdown Calendar,* at position 5 in the Google Play Store. Ten applications were available in both app stores, six only in the Apple App Store and three only in the Google Play Store.

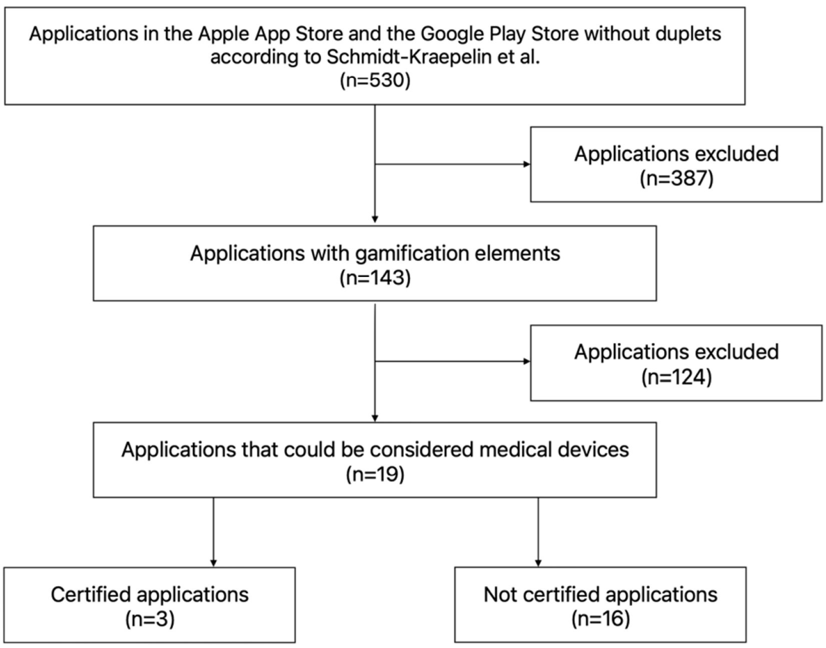

Figure 1: Flowchart of the in- and exclusion process

Of the 19 applications considered MDs, only 3 (15.8%) had the required quality labeling as MDs or the associated required evidence of quality, safety, performance, or benefit. We found that only the certified applications report evidence to validate medical claims. Of these three applications, two were labeled as class 1 MDs, and one was labeled as a Class IIa MD according to MDR.

The other 16 applications (84.2%) do not report being CE-marked or present evidence of effectiveness. Of these, three were accessory applications of hardware products and thus could be considered accessories of MDs, which should be labeled according to the main MD product. Four were ovulation or fertility trackers, which are intended to be used for fertility tracking and could facilitate conception. Thus, according to the Manual on borderline and classification under Regulations (EU) 2017/745 and 2017/746 - Version2 - December 2022, they should be certified as MD Class I [30]. Six products were management tools for different diseases. They are used for disease monitoring but are not intended to provide information for diagnostic or therapeutic decision-making purposes or for monitoring physiological processes. Thus, they should be classified as MD Class I [26]. The same applies to the patient-physician communication tool and the two stress reduction applications intended for treating or alleviating an existing disease.

5 Discussion

Although there are already evaluations and studies on the effectiveness of serious games and gamified products [8, 10, 12, 13, 16, 20-22, 25], little attention has been paid to the necessary certifications for medical use. With this pilot screening of an existing database, we address this research gap and present our first results. Out of 530 applications analyzed, 143 were gamified health apps. Among them, 19 (13.3%) qualified as MDs. Of these, it was only possible to identify evidence of the required approval as MD (such as the compulsory labeling) for 3 (15.8%), which all provided evidence of clinical validation. These certified apps provided validated medical claims, with two being class 1 devices and one Class IIa device under MDR. The remaining 16 apps (84.2%) lacked certification and evidence of safety and effectiveness. Among them, three were accessory apps and should be labeled accordingly to the parent product. The others were low-risk and would need Class I MD certification.

5.1 Limitations

This analysis has several limitations. First, the analysis is based on a dataset from 2018 and only considers app store applications with a commercial use case. Because the digital market is evolving rapidly, some results may be outdated. Extending the database to non-app store applications and more recent products would increase the validity. The certificates were not always available via a web search. In such cases, the developers were not contacted. However, these applications may be CE marked, but their certification may not be readily discoverable, even though it is required. Developers were also not contacted for clinical data or evidence, although public submission of clinical data or evidence is not required.

The definition of gamification by Schmidt-Kraepelin et al. (2018) used in the analyzed applications seems overly complex and extensive for this use case. The classification into different types of gamification is not necessary here. In the future, applying a more precise and straightforward definition based on the current state of knowledge could be helpful. Additionally, the applied rules of the MDR classification process are not specifically designed for SG and gamified applications. Thus, they do not consider their unique aspects and risks.

5.2 Future research

To provide developers with steps to avoid this and to assist in the accessibility of regulatory compliance and quality management in this area, an appropriate framework optimized for gamified applications and SGs would be helpful. Particular attention should be paid to which risk classes the products have and which steps and evidence must be provided for each class. However, no such quality framework exists and should be developed. Such a quality framework would likely be closely related to existing software human factors and AI frameworks. However, it would need additional considerations for the time-extensive and dynamic nature of users' interactions with SGs.

An important milestone for certifying gamified apps and SGs is proof of efficacy in high-quality studies. This evidence is lacking in some cases, or the existing studies are of poor quality, as systematic reviews have shown [8, 10, 12, 13, 16, 22, 33]. In order to assess the cost-effectiveness and superiority of these products over other therapy and motivation methods, these should be compared in controlled studies.

6 Conclusion

Currently, only a few commercial gamification products in the medical field can meet the standards required by medical device regulations, especially the MDR, making it difficult for consumers, patients, and healthcare providers to identify and use helpful apps. However, as more and more products like these seek to enter the market, it is essential to make developers aware of the need for MDR certification and the steps required to achieve it. This is the only way to ensure that the claims made by such applications are fulfilled and that users and patients are not put at risk. When developing a game or a gamified application for therapeutic use, these requirements should be considered right from the start. This way, delays in market entry and unplanned cost increases can be avoided.

These challenges need to be addressed promptly as new application areas for gamification and SGs in medicine continue to emerge, whether it is the gamification of the daily lives of healthcare professionals, therapy and lifestyle management of patients, clinical research in trials, or the use of VR or AR for surgical planning, training, and rehabilitation. Many of these use cases represent a good business opportunity, but most would be regulated as MDs.

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8 Vita

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