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Understanding of Gamification in Product Engineering – A Systematic Literature Review

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Abstract: This publication explores the use of gamification in product engineering, focusing on its role in product engineering processes (PEP). Through a systematic literature review, two primary uses are identified: adaptation of PEP methods and support for product design. Analysis also reveals that gamification, using game design elements in non-game contexts, predominantly aims to boost user motivation and engagement. An understanding of gamification in product engineering, highlighting its potential to transform PEP and design practices by enhancing user engagement and motivation, is proposed.

Keywords: Product Development, Design Methods, Design Activities, Gamification

1 Introduction

To overcome the challenges of today's product engineering, new methodological approaches are necessary (Albers, 2023). For such an approach, games have been used as a reference for some time now, resulting in a rise to the technique of gamification. It has been adopted across numerous industries, as evidenced by a variety of studies and applications not only within educational and medical fields but also in everyday life situations (Korn et al., 2022; Raczkowski and Schrape, 2018). However, considering that a significant proportion of gamification initiatives fails, it is crucial to comprehend the application of gamification to fully leverage its potential within product engineering (Burke, 2014). Gamification can generally be described as the use of game design elements in non-game contexts (Deterding et al., 2011a). Deterding et al. suggest not to restrict this definition any further, whereas other authors restrict the concept of gamification more strongly, e.g. by focusing on its digital application (Burke, 2014; Deterding et al., 2011b; Korn et al., 2022).

The publications aim is to develop a comprehensive understanding of gamification within the realm of product engineering. To achieve this, a systematic literature review is conducted to identify publications relevant to both product engineering and gamification, followed by an examination of the situations and purposes of the use of gamification in product engineering. Finally, a unified understanding of gamification in product engineering is derived from the systematic literature review and proposed.

2 State of the Art

Raczkowski and Schrape note the absence of a uniform definition of gamification, attributing this ambiguity to varied interests within the field (Raczkowski and Schrape, 2018). Hence, there is a plurality of definitions and examples of these are listed in Table 1. However, the most frequently used definition for gamification is the definition according to Deterding et al. and it is the main reference definition of this publication (Deterding et al., 2011a; Reiß et al., 2017). To understand this definition, it is important to note that the term "game design elements" refers exclusively to those elements that are characteristic of games. Furthermore, the concept of game and the concept of play are distinguished by the characteristic of games that they are, in contrast to play, based on a structure defined by rules and competition with respect to a goal. (Deterding et al., 2011a) Seaborn and Fels consider the purposes of gamification as exclusively those with a non-entertainment character (Seaborn and Fels, 2015).

Table 1. Definitions of gamification

Burke (2014)	Gamification is the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals.
Deterding et al. (2011a)	Gamification is the use of game design elements in non-game contexts.
Huotari and Hamari (2012)	Gamification is a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation.
Zichermann and Cunningham (2011)	Gamification is the process of game-thinking and game mechanics to engage users and solve problems.

A term frequently mentioned in the context of gamification is serious gaming. Deterding et al. characterize serious gaming as "*the use of complete games for non-entertainment purposes*" highlighting its distinction from the mere application of picked out game design elements as applied in gamification (Deterding et al., 2011b). Similarly, Seaborn and Fels differ between gamified, game-like systems and fully-fledged games (Seaborn and Fels, 2015). Stieglitz also defines serious games as games whose purpose go beyond pure entertainment while Laamarti et al. specify serious games as *„applications with three components: experience, entertainment, and multimedia"* (Stieglitz, 2017; Laamarti et al., 2014). The line between gamification and serious gaming often blurs, leading to confusion in their application. An example of the use of the term gamification for a serious gaming application is a fully-fledged game for learning problem-solving methods which is considered as gamification by the developers of the game (Reiß et al., 2017).

The successful application of gamification within the product engineering domain requires a thorough understanding of the activities during the engineering of a product. Product engineering encompasses all processes from the product or business idea to the series production start-up whereas the frequently mentioned product development is one of the three main task areas of product engineering and deals with systematically elaborating the development task (Albers and Gausemeier, 2012; Browning et al., 2006). The procedure for engineering a product can be mapped by a product engineering process (PEP) which can be visualized with the help of process models (Gericke et al., 2021). Process models contain individual process functions for which suitable methods are to be specified (Richter, 2017). One example of a process model in product development and product engineering is the integrated Product engineering Model (iPeM). The iPeM is a generic metamodel that comprises all the relevant elements for deriving situation-specific product development process models. (Albers et al., 2016) Originating from the descriptive model according to Negele et al. (1999), it integrates a system of objectives, an operation system, a process system, and a system of objects, and merges the operation and process systems into one comprehensive operation system. The operation system of the iPeM includes the following, partially adapted product engineering activities according to Albers and Braun which encompass all relevant fields of operation for product developers. (Albers and Braun, 2011; Albers et al., 2016)

- Manage Project: Management of the system of objectives and operation system
- Validate and Verify: Continuous comparison of target and actual state
- Manage Knowledge: Gaining, identifying, organizing, and developing data, information and capabilities
- Manage Changes: Coordinating technical, social and economic changes
- Detect Profiles: Identifying customer's, user's, and provider's behavior and characterizing the features of the product in development without limiting the solution space
- Detect Ideas: Finding solutions for addressing the product profile
- Model Principle Solution and Embodiment: Elaborating detected ideas while considering technical and economic aspects and connecting the desired functions with the physical/logical embodiment
- Build Up Prototype: Creating physical and virtual prototypes to perform the activity "Validate and Verify"
- Produce: Conducting the manufacturing processes for the final product
- Market Launch: Includes all activities regarding marketing (e.g. marketing strategy and distribution network)
- Analyze Utilization: Observing the user's behavior when using the product to anticipate the future users' behavior and identify improvement potentials
- Analyze Decommission: Observing the user's behavior regarding the product after the end of the product life cycle to find solutions for an eco-friendly decommission

Each situation within a product development process can be matched with a set of these product engineering and technical problem-solving activities, thereby enabling the verification of whether an activity is part of the fields of action within product engineering or not. Moreover, a survey indicated that the iPeM is particularly suitable for the selection of methods in comparison to other process models, e.g. the V-model according to VDI 2206 and the stage-gate process. (Albers et al., 2016) These methods can support the product engineering activities to achieve the aims of product engineering and development processes. They are defined by a "*rule-based and planned approach according to which certain activities are to be carried out in order to achieve a certain goal*" (Lindemann, 2009). Hindrances in searching for and selecting a suitable method as well as too great a gap between research findings and practical application result in low acceptance and limited awareness of methods that are suitable for the situations at hand (Beckmann, 2021; Pahl, 1994). To address this, methods are to be provided on a needs- and situation-specific basis (Reiß et al., 2015). Lindemann uses the criteria *purpose*, *situation*, *effect*, *approach*, and *tools* to describe methods. He uses the term *purpose* to describe which kind of aid a method can provide to support an activity within development processes, and the term *situation* to describe the context of the application including the problems and constraints for which the method is typically suitable. (Lindemann, 2016) The "Innofox" application, which provides product development methods for their users, relies on the criteria *objectives*, *desired results* and *relevant activity* with recourse to the iPeM for method selection (Reiß et al., 2015). Another tool supporting the selection of methods also provides information about *project phase*, *purpose* and furthermore *group size* and *needed effort* (VDI Verein Deutscher Ingenieure e.V., 2024).

To summarize, the demonstrated ways of describing methods contrast with the definition of gamification proposed by Deterding et al. (Deterding et al., 2011a; 2011b). They advise against narrowing down the concept of gamification, as they see no advantages in narrowing it down. Furthermore, the possibilities of using gamification in different specialist areas such as news, health and training would be limited. (Deterding et al., 2011b) On the other hand, there are the aforementioned hindrances that can arise from an insufficient description of the term gamification for the use in the domain of product engineering. One advantage that is missing for a more detailed definition according to Deterding et al. therefore may be better discoverability and support in the selection of a suitable method (Deterding et al., 2011b). The research gap is the lack of a unified, more detailed understanding of gamification in product engineering providing the needed information for a better discoverability of gamification and support in the selection of a suitable method for solving product engineering problems.

3 Methods

3.1 Need for Action

The already presented approach of Deterding et al. to keep the concept of gamification general may be advantageous when problems are approached with preconceived intention of using gamification (Deterding et al., 2011a; 2011b). However, as previously discussed, there is a significant risk that gamification will not be appropriately utilized as a problem-solving method within the PEP in relevant situations. Based on the preceding chapters the aim of this publication is to provide better possibilities to come across gamification for suitable problems and to evaluate its applicability for product engineers who are looking for a suitable method for solving a problem during the PEP. The following research questions are answered for these reasons:

1. What literature on the use of gamification, specifically focusing on product engineering, can be identified?
2. For which specific purposes and in which situations is gamification used in the identified literature?
3. From the current application of gamification in PEPs, what unified understanding of gamification can be derived?

To address the first research question, a systematic literature review is conducted to identify relevant publications. Given that Lindemann and the two previously mentioned applications all employ purpose/objectives and situation/project phase/relevant activity to describe methods, an analysis is conducted of the situations and purposes for which authors consider the use of gamification to address the second research question (Lindemann, 2016; Reiß et al., 2015; VDI Verein Deutscher Ingenieure e.V., 2024). This analysis includes both explicit and implicit references to situations and purposes. Based on this analysis, the results are examined for components that contribute to a potential unified understanding of gamification, and after these results have been discussed, an understanding of gamification in product engineering contexts is proposed.

3.2 Research Design

The procedure to answer the questions introduced in the preceding chapter is based on the Design Research Methodology (Blessing and Chakrabarti, 2009). In this publication, the first phase of the Design Research Methodology, the Research Classification, is conducted by analyzing the state of the research regarding the research questions. This process is divided into five phases, as shown in Figure 1.

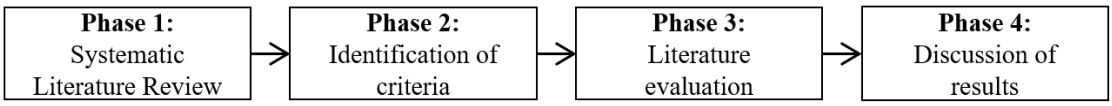

Figure 1. Phase diagram of the literature research

In the initial phase, the literature on the application of gamification within structured, general product engineering and development is reviewed to create a framework and a suitable search string. Using this search string, a systematic literature review is carried out using the Scopus database (www.scopus.com). Scopus was chosen to ensure the adequate quality of documents to counteract publications driven by vested, personal interests by only taking peer-reviewed publications into account while including a wide range of publications leaving out only a number of publications that was considered neglectable for the aim of this paper (Singh et al., 2021; Stahlschmidt and Stephen, 2020). The found literature is filtered step by step applying evolving criteria for filtering in each step pertinent to the research question. The used criteria and the timing of their application are shown in Figure 2.

From the findings of phase one, criteria for the evaluation of the use of the gamification term are derived in the second phase. These criteria may be binary (fulfilled / not fulfilled) or non-binary resulting in criteria for aggregating diverse

concepts under one umbrella term. They are selected to be suitable for addressing the second research question, for which the results of the Systematic Literature Review are analyzed. In the third phase, these criteria are used to evaluate the literature. The outcomes of this literature evaluation are visually presented through circular ideograms, Harvey Balls, for binary criteria, and as a compilation of concepts for non-binary criteria. A criterion is considered fulfilled if it is either explicitly addressed by the authors or if, during the analysis of other publications, significant similarities regarding the criterion with those publications where it is directly mentioned are observed, thereby making its fulfillment unequivocally assumable. Conversely, a criterion is deemed not fulfilled if there is no explicit mention, and the similarities with publications where the criterion is concretely addressed are insufficient to unequivocally satisfy the criterion. This stringent approach is employed to ensure that only intentional or clearly identified purposes are considered, as these are suitable for drawing conclusions about the methodical application. The final phase involves the discussion of these results. The different uses of gamification in product engineering are juxtaposed and evaluated considering the research questions. The outcomes of Phase 3 are utilized to identify uniform situations and purposes for which gamification is used in product engineering and to verify their validity in the field of product engineering. Based on these uniform situations and purposes, a proposal for a unified understanding of gamification in product engineering is presented.

4. Preparing and Conducting the Systematic Literature Review

4.1 Phase 1: Systematic Literature Review

The initial step of the systematic literature review was conducted after a general understanding of the research questions was gained and relevant terms that serve as suitable search criteria were identified. The focus was put on engineering and development processes where products are created within a structured and methodically supported framework. The terms *product development*, *product engineering*, and *product design* were used as inclusion criteria. Scopus was utilized for conducting the search using the established search string. To allow for a comprehensive investigation, no exclusion criteria were applied. The initial step of the systematic literature review yielded 174 results. The titles and abstracts of the found documents were checked for accessibility and language. This publication examines documents in English, focusing specifically on product engineering and development to exclude studies that do not aim to build a complete product. 44 documents were subjected to full-text screening, where it was examined whether at least one of the product engineering activities of iPeM was concretely addressed. Out of the 31 documents from the full-text screening, 26 were ultimately included. This decision followed the summarization two publications by partially the same authors within the same project and exclusion of four publications that deal with Gamification according to their own definition, but are clearly assignable to serious gaming, according to the definition used in this publication, a common simulation, or simple use of a 3D engine. The process of the systematic literature review is shown in Figure 2.

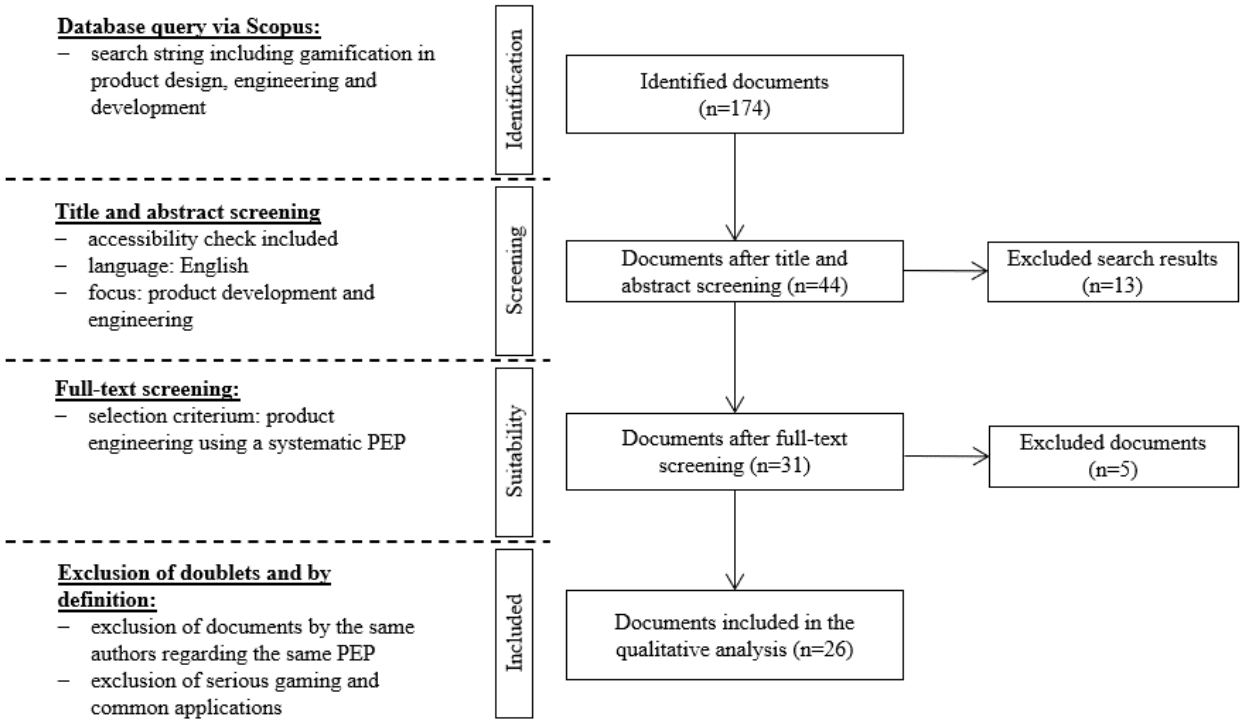

Figure 2. Condensation to essential publications in four stages

4.2 Phase 2: Identification of criteria

To meet the need to be able to better find methods and assess their suitability in the area of gamification, the potentials of gamification in methodical applications were explored. During the systematic literature review, it became evident that gamification is not used as a standalone method but always serves a supporting or complementary role. The methodical use of gamification can be divided into two cases: use for an *adaption of a PEP process or method by implementing game elements in the activities and steps*, or for *complementing and/or supporting the modeling of the principle and embodiment of a product by implementing game elements in the product*. This lead to two binary criteria for the literature evaluation. These criteria are suitable for describing the situations in which gamification is applied. Since the systematic literature review did not clearly reveal the purpose for which gamification is used, purpose was to be a non-binary criterion to collect the various purposes of gamification in the publications.

4.3 Phase 3: Literature Evaluation

The publications from the systematic literature review were evaluated based on the selected criteria. Not only direct mentions of the criteria were considered, but also indirectly mentioned application situations and purposes of gamification. All direct mentions of purposes were adopted; in the case of indirect mentions, an attempt was made to assign them to one of the purposes from the analysis of the direct mentions. Furthermore, both desired and undesired positive effects of gamification were taken into account. The purposes differ from each other as follows:

The criterion *enhancing attractivity* refers to the increase in overall product attractiveness. This broad term encompasses both the appeal to potential new users and the attractiveness for reuse, yet it does not address the intensity of use. *Influencing behavior* indicates the targeted modification of users' behavior, which can occur either transparently or without the users' knowledge. Not only user behavior during usage times is considered, but also behavior outside of usage times. The criterion *enhanced collaboration* describes improved cooperation among multiple users of the product. *Encouraging discussions* describes the purpose of stimulating discussions among multiple users by employing gamification. This criterion is not merged with the enhanced collaboration criterion, as it differs due to its specificity and it is not guaranteed that this always leads to an improvement in collaboration. *Enhancing engagement* outlines the purpose of getting users involved with something, focusing on a deeper level of product utilization rather than mere attraction, thus differentiating it from *enhancing attractivity*. The criterion *increasing fun* is largely self-explanatory and is listed separately because the authors distinguish it from the criterion of enhancing engagement, despite its general nature. *Enhancing idea generation* covers the promotion of creativity and its conversion into concrete solution ideas through gamification, without detailing how this process unfolds. *Enhancing motivation* describes the purpose of motivating users both during usage and for tasks outside of usage times. *Improving organizational processes and/or information flow* pertains to the enhancement of procedures within development teams up to entire organizations, especially in terms of communication processes. *Enhancing user experience* is a broadly used term by authors that does not allow for specification within the context of the rest of the publication.

The results are shown in Table 2, with a filled-out Harvey ball representing a fulfilled criterion and a not filled-out Harvey ball representing a not-fulfilled criterion. For reasons of presentation, the criteria enhancing engagement and enhancing motivation are shown as binary criteria, although they were not treated as such during the analysis, but as non-binary criteria.

Table 2. Usage of gamification in product engineering (abb. ImpOPI = Improving organizational processes and/or information flow)

	Situation of gamification use		Purpose of gamification use		
	Support/ comple-ment of product design	Adaption of a PEP process or method	Enhanci ng engage-ment	Enhanci ng motivati on	Other purposes
Batz et al., 2019	●	○	○	●	-
Bhatt and Chakrabarti, 2022	○	●	●	○	Increasing fun
Coskun et al., 2021	●	○	○	●	-
Fernandes et al., 2020	○	●	○	●	Encouraging discussions
Gasca-Hurtado et al., 2021	○	●	●	●	Enhancing collaboration
Huang et al., 2019	●	○	○	○	Influenced behavior

Ihamäki and Heljakka, 2020	○	●	●	○	Increasing fun
Jantschgi et al., 2020	○	●	○	○	Enhancing idea generation
Jreissat and Makatsoris, 2022	○	●	●	○	-
Leclercq et al., 2017	●	●	●	○	-
Méndez et al., 2020	●	○	●	○	-
Molasy et al., 2023	●	●	○	○	Enhancing attractivity
Palmquist, 2019	●	○	●	●	-
Patrício et al., 2021	○	●	●	○	ImpOPI
Peham et al., 2014	●	○	●	○	Influencing behavior; ImpOPI
Qalbi and Putra, 2020	●	○	●	○	-
Raftopoulos, 2015	○	●	●	○	-
Signoretti et al., 2015	●	○	●	○	-
Sjovoll and Gulden, 2017	●	○	●	○	-
Štiglic et al., 2023	●	○	●	○	-
Subramaniam et al., 2022	●	○	●	○	-
Tanaka et al., 2019	●	●	●	○	-
Villamil et al., 2023	●	○	○	●	-
Villegas et al., 2019	●	●	○	○	-
Xiao et al., 2020	●	○	○	●	Enhancing user experience
Yin et al., 2022	●	○	●	○	-

In total, 18 publications used gamification as a complement and/or support of modeling the principle and embodiment by implementing game elements in the product. Gamification was used to adapt a PEP process or method in 12 publications. Four of the publications meet both criteria, for example, when the gamified product was an application for conducting a gamified method. In every case, it was possible to assign the application of gamification to at least one of the two criteria. The evaluation also revealed that the use of gamification in each publication serves a supportive and/or complementary role with respect to the overall project and gamification is only employed as the main technique in the development of subsystems of the overall project. The purpose of gamification was in 17 cases *enhancing engagement*, in 7 cases *enhancing motivation*, and in 2 cases each *influencing behavior* and *improving organizational processes and/or information flow*. Further, once identified purposes included *enhancing attractivity*, *enhancing collaboration*, *encouraging discussions*, *increasing fun*, *enhancing idea generation*, and *enhancing user experience*. In one publication, no specific purpose of gamification could be identified.

5 Phase 4: Discussion of the Results and Proposal of an Understanding

In the last phase of the literature research, the results of the literature evaluation are discussed regarding possibilities for a unified understanding of gamification in product engineering. In the review of the identified publications, it becomes evident that within product engineering, gamification is deployed in two situations:

1. adaption of a process or method by implementing game elements in activities, steps etc.
2. complementing and/or supporting of modeling the principle and embodiment of a product by implementing game elements in the product.

Therefore, it is evident that gamification is not an independent method but rather supports, complements, or adapts methods and processes. The two mentioned situations are not mutually exclusive and can occur simultaneously. As a result, these two outcomes are considered the two situations in which gamification is currently employed in product engineering. The purposes of gamification in product engineering can be primarily narrowed down to two purposes. In 22 out of 26 publications, gamification was used with the goal of enhancing motivation and/or engagement. These two aims are very similar and can be considered as definitive purposes. Other purposes such as enhancing fun, enhancing

attractiveness, and enhancing user experience do not allow for a clear distinction from the two aforementioned purposes but can also be associated with them. The use of gamification to achieve improved organizational processes and/or information flow, enhanced attractiveness, enhanced collaboration, and encouraged discussions occurs to such a minor extent that this analysis cannot consider them as definitive purposes. Moreover, all these purposes can also be achieved through enhanced motivation and/or engagement, with the connections not being definitively clarifiable with the present analysis. Thus, it is assumed that, according to the current state of the art, enhancing motivation and/or engagement is the purpose of the use of gamification in product engineering.

With the identified situations and purposes, along with the characteristic features of gamification, a unified understanding of gamification in product engineering is to be synthesized. For the characteristic features, the definition by Deterding et al. (2011a) is referred to. Based on the current use of the art, the following understanding of gamification in product engineering is proposed: Gamification is a technique in product engineering that can enhance the motivation and engagement of the users of an adapted PEP subprocess or PEP method and of the users of products with a complemented or supported principle and design by using game design elements in a non-game context.

6 Conclusion and Outlook

The literature analysis conducted in this study indicates that there is currently an insufficient understanding of gamification in product engineering, which is necessary for the efficient and successful use of gamification. This includes supporting the discoverability of gamification-related methods and verifying the suitability of these methods. The situations and purposes of gamification use were analyzed in 26 publications identified via a systematic literature review after extensive filtering of 174 publications (Figure 1). The analysis revealed that there are two situations and two primary purposes for which gamification is used. Based on these and the definition of Deterding et al. (2011a), an understanding of gamification in product engineering was proposed.

Future work will explore the suitability of gamification in additional situations, analyze the relationships between the purposes used in the final proposal of understanding and other identified purposes, and identify further purposes for which gamification-related methods and processes can be utilized in product engineering. Moreover, the effectiveness of different applications of gamification will be examined, and recommendations for successfully using gamification in product engineering and design will be developed. In specific, the possibilities for use in product validation and Product-Production-CoDesign are to be evaluated and case studies regarding gamification of creativity methods are to be conducted. Serious gaming will also be used for this purpose and the different effects of serious gaming and gamification will be investigated. Special focus will be put on the long-term effects and a guideline for the clear distinction between gamification and serious gaming is to be developed based on the understanding of gamification proposed in this publication.

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