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Designing and Implementing Gamification: GaDeP, Gamifire, and applied Case Studies

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Abstract

Gamification aims at addressing problems in various fields such as the high dropout rates, the lack of engagement, isolation, or the lack of personalisation faced by Massive Open Online Courses (MOOC). Even though gamification is widely applied, not only in MOOCs, only few cases are meaningfully designed and empirically tested. The Gamification Design Process (GaDeP) aims to cover this gap. This article first briefly introduces GaDeP, presents the concept of meaningful gamification, and derives how it motivates the need for the Gamifire platform (as a scalable and platform-independent reference infrastructure for MOOC). Secondly, it defines the requirements for platform-independent gamification and describes the development of the Gamifire infrastructure. Thirdly we describe how Gamifire was successfully applied in four different cases. Finally, the applicability of GaDeP beyond MOOC is presented by reporting on a case study where GaDeP has been successfully applied by four student research and development projects. From both, the Gamifire cases and the GaDeP cases we derive the key contribution of this article: insights in the strengths and weaknesses of the Gamifire infrastructure as well as lessons learned about the applicability and limitations of the GaDeP framework. The paper ends detailing our future works and planned development activities.

Keywords: GaDeP, Gamification Design Process, Gamifire, Gamification, Architecture, Scalability, MOOC, Platform Independence, Infrastructure, Transfer, Evaluation, Validation

1 Introduction

Gamification was introduced to improve situations of motivational gaps or to foster a required behavioural change: applying game elements to boring activities adds fun and aims at increasing motivation [1]. However, the lack of systematic and scientifically sound design frameworks [2] leads to gamification approaches mostly relying on very limited sets of game elements relying on mostly extrinsic motivational factors (such as points, badges, and leaderboards) [3]. This way, gamification does not yet exploit its full potential [4].

On the other hand, *meaningful gamification*, which we understand as gamification that is thoughtfully designed to be integrated with the learning process, the learner, and the problem domain, using a composition of game elements [5] supporting the desired effects according to selected theories, can be beneficial to learners [6]. Our definition of meaningful gamification is related to Nicholson [7], who claims that no single gamification system will be beneficial to all users. We build on this definition but add the notion that gamification does not only have to account for the specific users but also be apt for specific problem domains.

The Gamification Design Process (GaDeP) aims at introducing a research driven method to support the systematic design of gamification tailored to the specific situation of an application scenario and a problem to solve within. We developed the GaDeP framework for the design of meaningful gamification [8, 9], which we will briefly describe below.

As initial field of application for GaDeP, we have selected massive open online courses (MOOCs). MOOCs, announced to improve worldwide education [10], come with downsides like high dropout rates [11] and low learners' engagement [12]. Designing meaningful gamification is complex and implementing it into MOOC platforms is another obstacle: platforms differ in technology, functionality and extensibility [13].

In order to apply and evaluate GaDeP, a two-fold approach is described in this article: firstly, we developed Gamifire as the GaDeP reference infrastructure for MOOC. In this article, we highlight the technical side of implementing Gamifire by introducing backgrounds and related works, describing our design and development approach, listing requirements, resulting in a description of the system architecture and implementation of Gamifire.

Secondly, we explore the general applicability of the GaDeP framework beyond its original scope by reporting on a study, where GaDeP has been applied by four student teams in their research and development projects as part of a serious game course assignment. We briefly describe these four projects, their outcomes, and the insights we gained.

Consequently, the main contribution of this article is the multi-perspective validation of GaDeP as a theory-based high-level framework for the gamification of online education: (1) the contribution of GaDeP to the development of Gamifire as an application independent gamification platform, (2) the application of GaDeP and Gamifire to various educational settings, and (3) the application of GaDeP by novice designers of gamified applications.

2 *Related Work and Background*

2.1 *Towards gamification design frameworks*

Based on a review of 24 papers, [4] analyses the question "Does gamification work?", claiming that gamification works and can have effects on psychological and behavioural outcomes. The article describes a framework to evaluate the effects of gamification as motivational affordance though they also reported that the studies analysed suffered from methodological limitations.

With the purpose of providing a complete overview and systematic mapping of the empirical research done in the framework of gamification in education 34 papers were analysed in [14]. According to the reported results, the field suffers from (1) a lack of "true empirical research on the effectiveness of incorporating game elements in learning environments", and (2) inadequate "methodology used in most of the empirical settings to test the effects of game elements". The authors express the need for more structured analysis approaches aiming to explain the effects of a particular game element on a specific target in the educational context. At this point, we aim to position GaDeP as a systematic design framework that bases strongly on a theoretical fundament guiding also the evaluation of the applications designed with it.

Frameworks for the design of gamification not only have to rely on measuring the effects of gamification but also need to look at the design aspects of games and game elements suitable for gamification. Björk and Holopainen's collection of game design patterns is an example of a structural framework analysing the composition of games and describing the purposefulness of selected game elements in designing games [5]. This approach can be seen as complementary to GaDeP in the sense that it can guide the game element selection, design and implementation phases of GaDeP (see section 2.2). Though not targeted specifically at gamification, the broad list of elements together with the selection criteria of reported effectiveness in previous gamification approaches, we follow the list of game elements in [5] as general game element framework. However, by no means this aims at limiting a gamification designer from choosing different game elements beyond the list of game design patterns.

Eighteen different gamification design frameworks are analysed in [2], some of which are general purpose frameworks, some designed for specific business purposes. The authors conclude, that while most of the frameworks focus on the human centered design process for gamification, they lack two basic aspects: a scientifically sound theoretical foundation inherent in the selection of design elements and a proper evaluation step, reflecting the needs of the theoretical foundation, which are exactly gaps, that GaDeP aims to fill.

Tondello et al. [15] report on ways to evaluate the gamification systems using gameful design heuristics. This approach evaluates gamification from a game-design perspective and can thus be seen as complementing GaDeP's evaluation phase, which aims at evaluating the gamification outcome from the perspective of the application domain. In this article, however, we take yet another perspectives: we validate GaDeP from the perspective of its implementability into a gamification platform and its applicability by new design teams.

In a previous literature review of 61 studies on the evaluation of gamification [3], we found 24 different game elements to be used (with a predominance of points, badges, and leaderboards), measuring effects on six different aspects: (1) performance; (2) motivation; (3) engagement; (4) attitude towards gamification; (5) collaboration; and (6) social awareness. The results of these different studies where not comparable in all cases. Together with the above stated lack of consistent design methodologies, this variety of game elements and effects motivates our research towards GaDeP as a consistent framework for designing meaningful gamification as described in the next section.

Tondello et al., [15, 16] report different numbers of game elements useful for gameful design and gamification. These differences stem from two main factors: (1) our review focused on gamification in online education and (2) we omitted all approaches that did not report empirical findings.

2.2 GaDeP - The Gamification Design Process Framework

Based on the lack of a consistent and sound design framework for gamification as identified in our related work, GaDeP has been introduced as a framework complementing and completing the existing frameworks and specifically addressing the lack of theoretical soundness and the missing support of empirical evaluation of the gamification design per se. In this sense, GaDeP aims especially at being a framework for *meaningful gamification*. In [8, 9] GaDeP is described in detail. For the purpose of this article, we briefly summarise the main aspects, as depicted in fig. 1.

GaDeP comprises six phases, which are iteratively performed as part of a continuous improvement cycle. GaDeP focuses on meaningful gamification design relying on a methodologically grounded approach towards designing and implementing gamification solutions tailored to the specific needs of the application scenario at hand. GaDeP's six phases are:

1. *The analysis of the application scenario* requires to focus on the context of application of our gamification design, its specific aspects, issues, requirements, target groups and other contextual parameters. In this phase, one may already point to general problems typical of the application scenario but usually these stay on an abstract level.

2. *The problem definition* requires to focus on a specific problem that the designer of gamification aims to address, from an abstract level there is the need to pass to a more practical and operative one.

3. *The theoretical framework* helps to understand the background of the problem and how to address it. It is a crucial phase, that requires to find and select appropriate theories

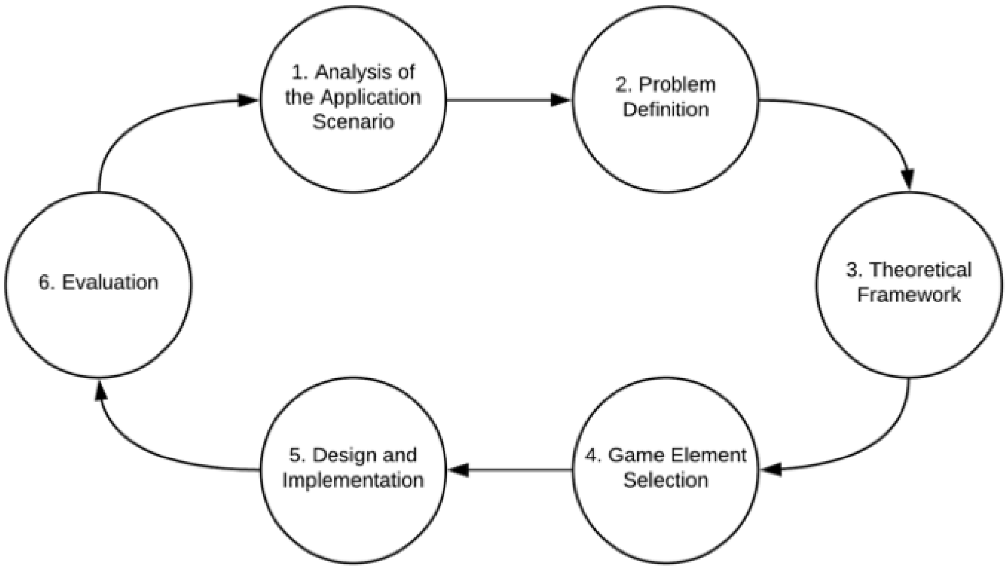


Figure 1: *The GaDeP framework (from [8])*

from the literature, which are applicable to the problem and the application scenario. The theoretical framework utilises these theories and serves as a reference to guide the following phases.

4. *The game element selection* implies looking at game element collections to find suitable ones to address the problem and the characteristic of the application scenario, while keeping the theoretical framework in mind.

5. *In the design and implementation* phase the gamified solution is realised according to the outcomes of the previous phases, which makes this the practical phase of the framework.

6. *The evaluation phase* is required to measure the resulting effects of the chosen gamification design (per each game element, if possible). Here it is important to refer to the theoretical framework and the problem definition, to identify the effects and variables to be measured. The evaluation can not only be seen as final evaluation but also as monitoring of the design as input for further improvement.

A method comparable to GaDeP has been proposed by Deterding [17]. While Deterding's method of "Gameful Design" focuses strongly on user needs and the detailed design process, GaDeP can be seen as complementing this with a perspective on the specific problem domain to be addressed by gamification and selecting according theoretical approaches for addressing this problem. While GaDeP itself does not propose a specific game design process, it is open to apply methods like gameful design or the game-design pattern approach during the design phase.

More recently, [18] discuss a social collaboration oriented approach towards gamification. While their approach collects relevant requirements and design elements towards social collaboration it does not aim at defining a general gamification design method or engineering approach. A gamification model for entrepreneurship education and skill dissemination using exposure related game elements (such as leaderboards or badges) for dissemination purposes is discussed in [19]. In relation to the work done for GaDeP, this approach represents a new problem domain, which, however, lacks the theoretical underpinning required by GaDeP.

2.3 Towards implementing gamification: platform requirements

Design frameworks, such as GaDeP, need to lead to implemented gamification solutions in order to be considered to be successful. To prepare our technical implementation of Gamifire as reference infrastructure for GaDeP, we will look at the requirements derived for other gamification platforms. Thus, we reviewed several sets of requirements towards the implementation of gamification.

A categorization of gamification requirements for business applications is reported in [20]. In contrast, we derive requirements focusing on the context of open distance education. A corresponding gamification architecture [21] provides basic elements for a gamification platform, likewise focused on business platforms, lacking the openness required for platform-independence. A gamification framework for K-6 education is reported in [22]. The authors collect elements for educational purposes and derive motivational goals, without reporting technical aspects. Another gamification platform focuses on software development processes [23], where specific software development tasks and process elements are gamified.

Morschheuser et al. [24] propose an engineering-focussed method for gamified systems based on the identification of 13 design principles comprising seven design steps (Project preparation, analysis of context and users, ideation, design, implementation, evaluation, monitoring). This method has quite some overlap with GaDeP. However, GaDeP's focus is more on the theoretical background selection, aiming to base the subsequent design phases on theoretical considerations, while their focus lies more in the design process itself. The thirteen design principles collected in [24] also complement the requirements we collected towards the development of Gamifire.

Palmquist [25] reports on a study comparing the design process for adding gamification to already existing systems with the design of gamified solutions from scratch. The resulting architecture for adding gamification to existing systems is comparable to that of Gamifire. However, Gamifire's focus is on the gamification of online learning adding aspects of game-element collections, evaluation aspects and data collection, where Palmquist focuses more on the component architecture.

With OneUp-Learning [26, 27] propose a platform for the gamification of courses, which is comparable to the ideas of Gamifire, by providing gamified education. However, their platform is a fully integrated system, which requires existing materials to be transferred into this environment, while gamifire aims at providing gamification to existing learning environments.

Similar to the mentioned approaches, we aim at providing a gamification platform for online learning processes, based on the specific requirements of this domain. Using GaDeP as underlying design framework we aim at achieving meaningful gamification. We add platform independence, scalability, and a focus on MOOC to our requirements. However, we are aware that meaningful gamification and platform independence are in conflict: the former requires for a tight integration of the gamification design with the learning processes, while the latter calls for loose coupling of the components to allow for reuse in different technological settings. We will get back to this conflict in our research design.

3 Research Design and Methods

As highlighted in the introduction, with GaDeP we aim at providing a systematic gamification design framework for meaningful gamification, that could be applicable to a large variety of application cases. In our research design we consequently explore two important aspects: (1)

the in-depth analysis of requirements towards implementing Gamifire as reference infrastructure for GaDeP applied to MOOCs; and (2) the applicability of GaDeP in contexts different than MOOCs.

3.1 Implementing Gamifire

Applying gamification to MOOCs is complex: the amount of possible design variations is nearly endless and the design process comprises a number of decisions to be taken from interdisciplinary perspectives, such as: game design, psychology, learning science, technology-enhanced learning, human-computer interaction, and software engineering [28]. Many gamification attempts fail due to the lack of a clear design methodology, that helps to design related to the context, the target group, the problem, and a theoretical framework [2]. Further, different MOOCs vary significantly in their didactic approach, their target groups, and other specific aspects. Thus, they may suffer from quite different problems such as dropout rates, isolated learners, or lack of engagement. Therefore, we investigate the following research questions in order to develop Gamifire based on the GaDeP framework:

- (RQ1) Can we develop a platform-independent, scalable platform to support the meaningful gamification of MOOC according to the GaDeP framework?
- (RQ2) Can we resolve the conflict between platform-independence and the required platform integration for meaningful gamification?
- (RQ3) Can Gamifire support a variety of educational settings as required by different MOOC designs and their didactic contexts?

To answer RQ1-RQ3 and to base Gamifire on solid grounds, our approach comprises three main perspectives:

1. A *design perspective*, combining game design with problem-based selection of theories into an evaluation-based continuous improvement cycle.
2. A *user-experience and usability perspective*, taking the interplay of learning environment and gamification into account.
3. A *software-engineering perspective*, transforming outcomes of the other perspectives into implementable requirements and architectural specifications.

In [8, 9] the first two perspectives are extensively covered. Consequently, section 4 takes the software-engineering perspective, covering steps (4-6) of GaDeP in the field of MOOC. Section 5 summarises a number of validation studies, where Gamifire was used for the gamification of various MOOCs highlighting only those aspects that contribute to the software-engineering perspective.

3.2 Applying GaDeP

GaDeP can be seen as a high-level design framework, as it aims at being independent of a specific application domain and problem context. Also, it does not prescribe a specific choice of theories or prescribes a selection of game elements. Consequently, it is very generic and applicable to very many different situations.

This can be seen as a strength and weakness at the same time, as it leaves the designers applying GaDeP with the choice of theories and methods for each phase. At this point GaDeP does not aim to go deeper into the design process, in order to not limit the general applicability. However, for future versions of GaDeP, we plan to better align it with existing and emerging low-level frameworks that complement specifically the design process in a specific problem domain.

To understand, if the GaDeP framework can be helpful outside the MOOC context and if it can be applied by designers and developers independent of the research team that introduced GaDeP, we further explored the following research questions:

- (RQ4) Can GaDeP be applied to application scenarios outside the MOOC context?
- (RQ5) Can designers independent of the original inventors of GaDeP and not previously acquainted with it apply it to develop gamified applications?

To answer RQ4 and RQ5, we describe a case study of applying GaDeP to research and development projects performed by student teams as part of a serious games and gamification course taken in summer 2019. The details of this study are reported in section 6. Instead of evaluating the outcomes of the student projects, with this study we aim at evaluating the general understandability and applicability of the GaDeP design process and thus rather look at how the different steps of the GaDeP process have been understood and performed by the students.

4 Towards Gamifire - Implementing GaDeP for MOOC

4.1 Requirements

The requirements for Gamifire are based on the application field and the gamification framework GaDeP (see table 1). Our *Field of application* is online learning in MOOCs. This defines (non-functional) attributes of the user environment and technical constraints. The *gamification methodology* defines functional aspects. It requires game elements and user processes to be interwoven. This impacts the selection of game elements and the way the MOOC platform and the gamification platform are integrated. Based on game elements selected in [8] we reflect this from a software engineering standpoint. As it is not our goal to cover all possible game elements in Gamifire, we restrict to the selection of those we found to be relevant in the context of our application domain: MOOC.

Table 1: *Non-functional Requirements related to the Field of Application (Nx) and Functional Requirements related to the Gamification Methodology (Fx)*

No.	Requirements Description
	Non-functional Requirements related to the Field of Application (Nx)
N1	*Scalability*. MOOCs are designed for high numbers of learners. The gamification platform has to serve this amount of learners without significant run-time impact. This comprises scalability in terms of computing power, data storage, and network traffic.
N2	*Platform independence*. As different MOOC platforms exist, a gamification engine should cover many of these. At the same time, the integration of gamification into the target platform needs to be seamless in order to deliver a continuous learner experience.
N3	*Content integration*. Many game elements only make sense in connection to the content. The gamification engine needs to allow for these connections by tracking learner progress and learner interaction.
N4	The *User experience* of learners interacting with the MOOC platform should be enhanced by the gamification engine.

Requirements (cont. table 1)	
No.	Requirement Description
N5	*Extensibility*. The platform should be easily extensible to additional use cases. This covers adding new game elements, adapting existing game elements, or adding other functionality.
N6	*Stability*. The platform should provide a stable and reliable service with minimal human intervention.
N7	*Security*. The platform needs to store user related data in a secure way.
N8	*GDPR*. The data storage needs to be GDPR compliant.
N9	*Multi-user support*. Online learning may lead to a feeling of isolation, even if numerous learners share the same platform. Thus, the platform needs to support collaborative or competitive multi-user game elements.
N10	*Web front-end*. MOOC platforms are commonly accessed via web-browsers. The gamification platform needs to offer web front-ends.
N11	*User Group Size*. The gamification platform and the choice of game elements should not restrict the number of MOOC users.
N12	*Seamless integration*. The user interface (UI) of the gamification platform needs to integrate with the MOOC platform to appear as part of the MOOC UI without the user having to navigate between the systems.
N13	*Responsive UI*. The design, layout, and interaction mechanisms used should adapt to various end-user devices. The UI elements added to the MOOC should support all platforms the MOOC platform supports.
	Functional Requirements related to the Gamification Methodology (Fx)
F1	*Data collection*. GaDeP requires an evaluation step to be performed. To measure effects in different experimental settings requires to collect data about learner interaction in a flexible but structured way.
F2	*User management integration*. MOOC users register with the MOOC platform. The gamification platform needs to gather user information to avoid double registrations to provide the personalized service to the user (e.g. displaying individual information in the HUD to the MOOC user).
F3	*Choice of game elements*. The platform shall support a variety of combinable game elements to provide meaningful, gameful interaction. In the context of MOOC, these should according to GaDeP comprise at least the ones listed in F4-F12
F4	*Communication*. The platform needs to support synchronous and asynchronous forms of communication.
F5	*Stimulated planning* helps users to plan activities and to follow that plan. It thus requires functionality for planning, plan-based feedback and communication.
F6	*Clans* (or Guilds, Teams) organize users into groups, which can receive group-related assignments for collaborative or competitive work. Unlike open communities, clans are rather small, defined groups, that aim at remaining stable over some time. This requires support for the grouping phase and group-based concepts of content visibility and access.
F7	*Collaboration and Cooperation*. Group members should be able to work together on some tasks.
F8	For *Group competition*, groups need some form of group-privacy to hide working progress from other groups.

Requirements (cont. table 1)	
No.	Requirement Description
F9	*Individual and group challenges* are assignments to be solved according to constraints (e.g. time limits, number of attempts, competition/collaboration modes). Challenges shall motivate users and are (usually) not part of the formal learning success calculation but count for users' engagement and may contribute to perceived social presence and sense of community.
F10	A *Narrative* presents learning content with a story line, that connects learning episodes and contextualizes learning content with this story. The gamification platform should allow to include narrative elements.
F11	In games *Head-up displays (HUDs)* show contextual information to the player. The gamification platform should include HUDs for relevant information in a non-intrusive way, to support the learning process and not interfering with it.
F12	*Avatars*. Users should be able to personalize their appearance in the game, by using an avatar representation.

4.2 Gamifire

This section describes the design decisions leading to the architecture and implementation of Gamifire based on the requirements. It also reports on trade-offs and limitations.

To have many of the listed requirements covered on platform-level, Gamifire is implemented on top of the Google App Engine (GAE) cloud platform using a three-tier architecture, with database back-end (cloud data-store), application server, and front-end user-interface (UI) widgets. Choosing GAE enables us to meet the following requirements immediately:

- *Scalability (N1)* and *Stability (N6)* are core principles of GAE.
- *Extensibility (N5)* Gamifire is distributed as an open source solution[1].
- *Security (N7)* and *GDPR compliance (N8)* are inherent aspects of GAE.
- Support for *web front-ends (N10)* is supported within GAE.
- GAE's native session management delivers *multi-user support (N9)*.
- For *Data collection (F1)* Gamifire stores interaction information in the back-end data-store and supports treatment/control groups.

Covering (F1), the back-end stores log information about user interactions, time-stamps, and progress related data. The application server handles user related sessions, tracks user interactions, manages logging operations and generates feedback and UI-related content.

With platform-independence (N2) in mind, Gamifire uses user interface widgets to integrate into the MOOC platform through front-end integration. No back-end integration has to be performed (integrating data models, server interaction, session management or other back-end services). However, each game element/widget can store widget specific data. From the MOOC platform, Gamifire gathers the user, who is currently logged in and synchronizes Gamifire's user data with the MOOC at hand. In combination with the multi-user support and the scalability, this allows to support the same *user group size (N11)* as the MOOC platform itself.

[1] A public distribution of Gamifire is currently under preparation

To generate the UI in line with the front-end integration approach, Gamifire comprises a library of game element widgets, which provide the individualized views with respect to the user status. These widgets are embedded into the MOOC platform by adding them to the web-based front-end of the MOOC platform as HTML components. Through JavaScript introspection, they gather user information from the MOOC platform to synchronize user sessions and data between MOOC and Gamifire. Fig. 2 shows the Gamifire component architecture and its integration into a MOOC platform. Fig. 3 shows selected UI components displaying different game elements and components.

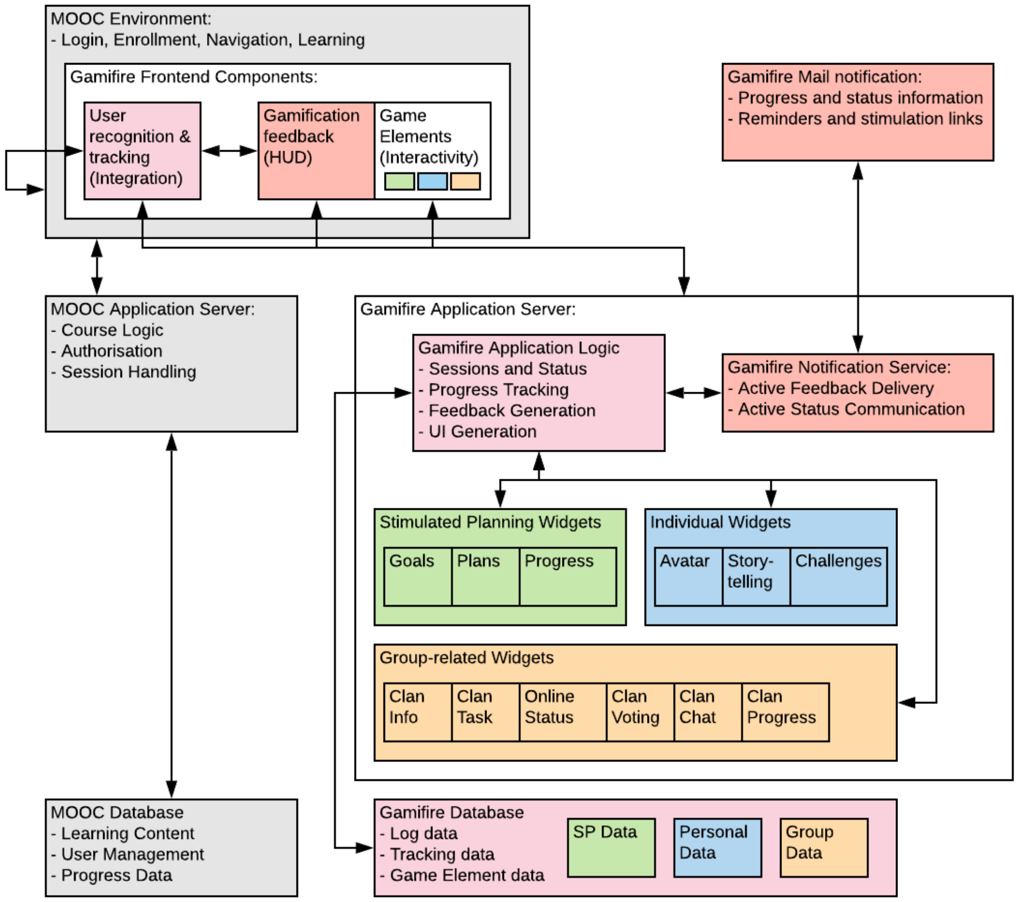
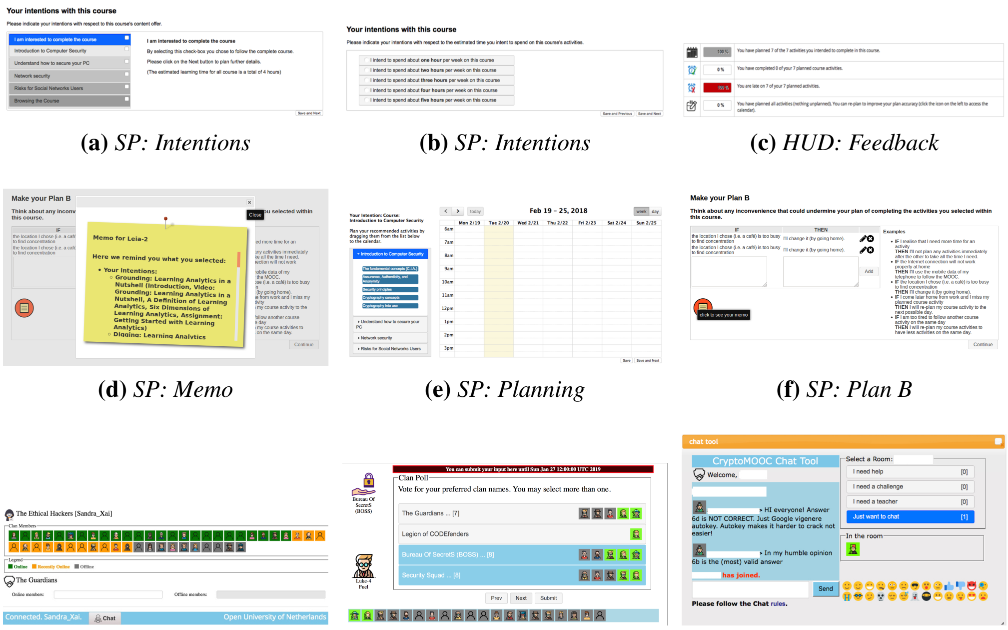


Figure 2: *Architecture of the Gamifire platform*

Content integration (N3) is in conflict with platform-independence. In section *Trade-offs and limitations* we discuss this situation. To keep the *user experience (N4)* close to the MOOC environment, we use style-sheets in Gamifire's front-end to adapt look and feel to the MOOC environment. This also supports the creation of responsive *UI components (N13)*. In combination with the front-end integration, this also supports seamless integration into the MOOC platform *(N12)*, where an important aspect of the front-end integration is the recognition of the user logged into the MOOC platform, which supports *user management integration (F2)*

Gamifire supports a number of game elements, as represented by the game element front-end components and the game element widget library: stimulated planning widgets, individual game element widgets, and group-related widgets. With this collection of game elements, requirements *F4-F12* are covered: *stimulated planning* is directly supported with a set of



(a) *SP: Intentions* **(b)** *SP: Intentions* **(c)** *HUD: Feedback*

(d) *SP: Memo* **(e)** *SP: Planning* **(f)** *SP: Plan B*

(g) *HUD: Online status* **(h)** *Clan voting* **(i)** *Clan chat*

Figure 3: *Screen-shots of Gamifire UI components.*

specific widgets and front-end components *(F5)*, the set of group-related widgets and components support *communication channels (F4)*, *clans (F6)*, *collaboration* via clan tasks and clan voting *(F7)*, *competition* via online status and clan progress *(F8)*, *individual and group challenges (F9)* are supported via challenges (individual) as well as clan tasks (group). *Narrative* is supported with specific information components as individual game element *(F10)*. The *HUD (F11)* combines the Gamifire application logic with the gamification feedback front-end. The user avatar component implements the game element *avatars (F12)*. The avatar is used to personalize the feedback component and online status, clan voting, clan chat, clan tasks and clan progress. With this coverage of game elements in Gamifire, also requirement *F3 (choice of game elements)* is covered. However, we do not claim completeness: additional game elements are planned to be added to Gamifire for a broader support of application cases and gamification scenarios.

4.3 Trade-offs and limitations.

The most striking trade-off we faced during the development of Gamifire is between the *platform-independence (N1)* and the concept of meaningful gamification *(F3-F12)* combined with the functional-requirement for seamless integration *(N12)*: while the former requires us to rely on shallow integration of Gamifire and the MOOC environment by means of front-end integration, the latter requires some understanding of the learning content and the corresponding learner progress within Gamifire. We addressed this trade-off with the following concept: when preparing a gamified MOOC, Gamifire is configured with a mirrored content structure (only the outline, not the contents itself), assigning content ids to recognizable page URIs. Through the tracking feature of the front-end integration, Gamifire can thus keep track of learner interactions within the MOOC and calculate interaction rates, learning progress, completion rates, etc. on its own data without having to query the MOOC platform's back-end. While this solution allows to keep the technical integration independent, it requires some extra effort to mirror the content structure into Gamifire. Especially, when a MOOC undergoes many changes, this may represent a bottleneck and a source of possible mistakes.

While this article mainly focuses on technical aspects, conflicts may also arise in the combination of game elements: narrative e.g. is in conflict with stimulated planning. A narrative connects learning contents into episodes of a story, stimulated planning allows users to plan individual learning activities, which requires a degree of independence. Gamifire does not automatically detect such conflicts and it is in the responsibility of the design team to make sure that the game elements used are not in conflict with each other.

The shallow integration according to the required platform-independence leads to another conflict in relation to narratives: narratives can be seen as part of the MOOC content but also expected to be part of the gamification design. For now, Gamifire does not resolve this conflict with a technical solution but leaves it to the course and gamification design team to resolve, where to apply which elements of a narrative: at this point learning design and gamification design need to be performed as a team-work.

5 Applying Gamifire to MOOCs: four Cases

Even though the architecture and implementation of Gamifire meet the requirements set out in section 4.1, a proof of the applicability of the solution can only be achieved by applying it to a variety of cases. Gamifire has been applied to four different application cases, where different game elements have been selected and implemented due to a different focus of the application case.

The studies reported here have been published in detail in [3, 9, 29]. To avoid replication, we focus here on the insights gained relevant to the technical aspects of the Gamifire implementation.

5.1 Initial Gamifire: stimulated planning, usability, platform-independence

In a MOOC on information security, we explored the impact of planning behaviour on goal achievement by implementing the game element "stimulated planning", inspired by [5] and according to the implementation intention theory [30]. We implemented Gamifire with widgets and functions for participants to (1) state their goals, (2) plan their activities (including a coping plan for inconveniences) and (3) to receive plan related feedback, and re-planning reminders, when the plan was not met. This first version of Gamifire was originally applied to Moodle and then transferred to Open EdX. It underwent a usability study [9], which informed the further development of the platform. The platform switch from Moodle to Open EdX also generally confirmed the platform-independence (N2) of Gamifire, by restricting the number of modifications necessary mainly to the front-end integration scripts.

5.2 Extending Gamifire: scalability for social presence and sense of community

Using a MOOC on cryptography, we aimed at fostering engagement through the development of perceived social presence and the development of a sense of community among users [31]. Several game elements (clans, avatars, group activities, communication channels, online status) were designed and implemented in Gamifire to achieve the purpose [32].

Group awareness and team interactions were at the focus of this version of Gamifire, requiring fast updates and exchange of status information, activities, and communication, to allow Gamifire to keep group members informed about other group members' activities and states in close to real-time [29]. Technically, the real-time requirement combined with the necessity to allow for high numbers of users, lead to the implementation of server communication balancing mechanisms, caching mechanisms, and load balancing mechanisms into Gamifire to allow fast communication without increasing server load too much.

5.3 Improving Gamifire: revisiting stimulated planning

A MOOC on trusted learning analytics has been chosen for an updated version of the stimulated planning game element, of which the use of the original version was already described in section 5.1. Specifically, in this improved version of Gamifire we addressed usability issues as highlighted in the eye-tracking study [9], which lead to more visual and less textual feedback, clearer wordings and improved arrangement of UI elements. The full detail of this study and the measured effects is available in [33, pp. 115–117], of which we will briefly just summarise those aspects relevant for the technical validation of Gamifire.

With respect to technical improvements of Gamifire, the main outcome of the study was, that the users in the treatment group who used the stimulated planning had a significantly higher average percentage of completed goals compared to users who did not use it. This impact of the voluntary use of the planning tool on goal achievement was also in line with the observation of increased system interaction when plan related notifications were sent to users. As technical requirement for future improvements of the system we took away some important lessons:

- The planning tool needs to be better integrated into the general planning environment of users (such as their regular calendar tool or task planning systems). This adds to our general requirements the need to include interfaces to general workplace tools, simplifying the range of tools users need to get used to.
- The notifications sent out by the system should also include those people who did not yet use the planning tool. This requirement adds to the notion, that people need reminders and nudges to achieve their goals, especially if these goals are not related to their daily routines.
- Instead of starting with an empty plan, it might be good if the system would offer predefined plan templates according to each user's intentions (e.g. learning time per week), which then only need to be tailored by the learner. This adds a usability requirement to our list, stating that a system should provide a high level of comfort to the user.

5.4 Using Gamifire: data collection in non-gamified MOOC

To test Gamifire as a scalable data collection tool, we used it in a non-gamified MOOC on marine pollution without applying specific game elements. In this MOOC we aimed at collecting student interactivity data for an A-B-Test designed within the features of the MOOC platform. The data collected are still under revision, however Gamifire supported a high number of participants, which allowed us to specifically focus on testing and proving of the scalability aspects of Gamifire's back-end infrastructure.

6 Beyond MOOC - Exploring new use cases for GaDeP

In the application cases described above, we have used the GaDeP methodological framework and the Gamifire technological platform in the context of MOOCs. Within these cases, we gathered important data and insights about possible improvements, especially with respect to the technological platform and its concrete implementation in Gamifire.

While the application cases above show the general applicability of GaDeP, limitations are that GaDeP has not been applied outside the field of MOOC and that the previous application cases have been performed by the team that invented GaDeP. There are thus two missing steps in the further validation of GaDeP as a generally relevant design framework: its application to scenarios beyond MOOC in order to learn about its general applicability (addressing RQ4) and its utilisation by people who were not involved in the research leading to its design in order to learn about its comprehensibility (addressing RQ5). In order to explore these two RQs, we designed the following study in the context of a serious game design lecture and project assignment taught to master level students in Summer term 2019 (April-May).

Participants: Fifteen students participated in the course, which took part over a time span of six weeks with one weekly lecture, one weekly interactive group session, unsupervised project work time, and a final presentation and assignment submission. The participating students were second semester master students (14 male, 1 female, age range from 23-33 with an average of 30). The students had prior experience in developing game prototypes. None of the students had prior substantial knowledge about serious game design, gamification, or the GaDeP framework. The students were divided into four groups, composed by three to four members each.

Assignment: the groups were asked to conceptualise and develop a prototype of a gamified application or a serious game by applying GaDeP. Concretely, they had to go through all steps of GaDeP in the way listed below, but received in some phases support to allow them to reach their goals in the limited course runtime of six weeks. Also, each week's lecture was used to review the outcomes of the previous group session, to advice for possible improvement and to introduce and prepare the subsequent steps.

1. *Application scenario analysis*: each group should select a real-world scenario of their choice that they aim to address.

2. *Problem definition*: the students had to analyse and address a specific problem within their scenario.

3. *Theoretical framework*: each group had to find appropriate literature which helps them to understand theories/approaches of addressing the selected problem. Here the students received some examples for theories based on our previous cases but were asked to find different/additional ones.

4. *Game element selection*: based on the selected problems and theories, each group should select appropriate game elements and mechanisms for their prototype. Also here, they received a reduced list of examples based on the collection of [5] to simplify the selection. With this input and the theoretical framework of step 2 at hand the students had to do two things: (1) search for literature supporting the selection of appropriate game elements, and (2) come up with further game elements based on their own game design experience.

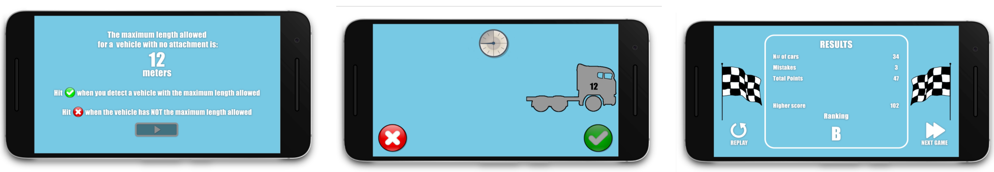
5. *Design and implementation*: each group should showcase a minimal prototype of their concept including an initial visual design, interaction flow, and first technical implementation.

6. *Evaluation*: the evaluation itself was not part of the course, but each group had to come up with an evaluation concept for their prototype specifying the evaluation goal, the variables to measure and the evaluation approach.

Results: All four teams and all fifteen students completed the course and handed in their final assignment and showcased a prototype. Tables 2-5 summarise the outcomes of each of the four teams per each phase of GaDeP, the figures 4-4 show impressions of the resulting prototypes.

Table 2: *Outcome summary for team 1*

Step	Phase	Outcome
1	*Application Scenario*	Driver License Education: more than one million driver license exams take place per year in Germany. Over the last years, the theoretical requirements have been raised.
2	*Problem Definition*	High failure rates in the theory-based exam, partly due to the high amount of factual numeric knowledge needed
3	*Theoretical Framework*	Mental number line as theoretical approach to learn numeric values better
4	*Game Element Selection*	Minigames for the different kinds of numerical questions tailored to speed, distances, weights, sizes, time, and formulas. Objects to be judged numerically placed on mental number line
5	*Implemented Prototype*	Mobile phone application for driver license training with minigames for numerical learning tasks. Fig. 4a-4c show impressions from the resulting prototype.
6	*Evaluation Plan*	Two fold evaluation approach proposed: 1. evaluate app against traditional learning material, 2. evaluate mental number line in congruent vs incongruent representations to evaluate key theoretical concept



(a) *Instruction* **(b)** *In-game scene* **(c)** *Feedback*

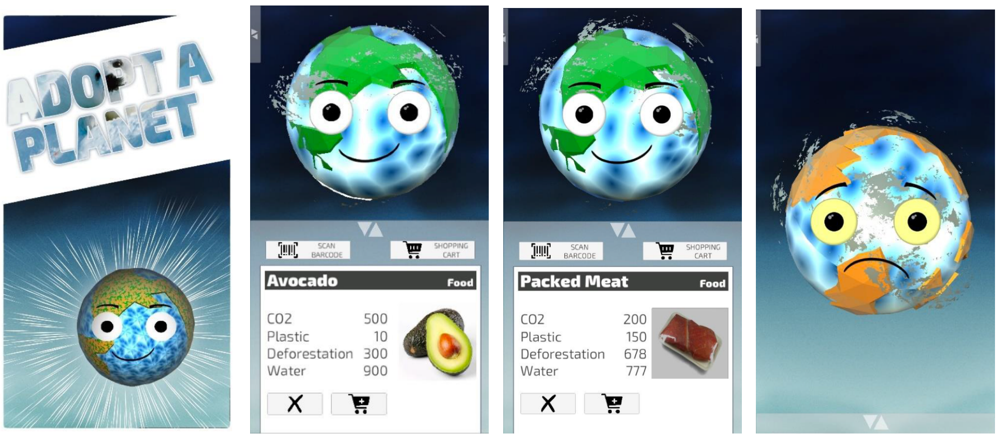
Figure 4: *Screen-shots of project prototype "Driver license education" (team 1)*

Table 3: *Outcome summary for team 2*

Step	Phase	Outcome
1	*Application Scenario*	Fighting Climate Change: climate change has become a global threat, which requires change on various levels (individual, regional, national, global) to be addressed
2	*Problem Definition*	Individual shopping behaviour contributes to climate change, but individuals are hard to address at larger scale
3	*Theoretical Framework*	Anthropomorphism helps identifying with non-human objects and life forms, visual rhetoric helps understanding, conditioning helps to train behaviour

Outcome summary (cont. table 3)

Step	Phase	Outcome
4	*Game Element Selection*	Avatar: planet earth as beingPoints/Rewards for good shopping behaviourAchievements for collecting itemsSocial Graph for collaboration and competitionGoal Indicators help to reach goalsStorytelling raises understandingEmpowerment gives control to the player
5	*Implemented Prototype*	Shopping assistance application allowing to scan bought items, which positively or negatively influence game stats visualised in the healthy and mood status of the earth as main game avatar. Fig. 5a-5d show impressions from the resulting prototype.
6	*Evaluation Plan*	Evaluation through playtests with initial groups and longer term evaluation through user behaviour observation and in app data collection

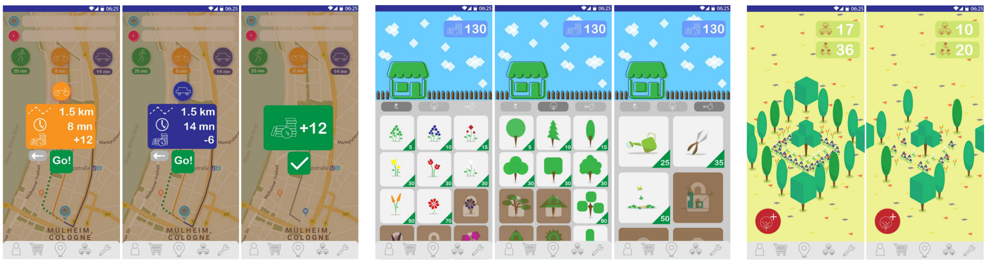


(a) *Title* **(b)** *Shopping 1* **(c)** *Shopping 2* **(d)** *Suffering planet*

Figure 5: *Screen-shots project prototype "Adopt a Planet" (team 2)*

Table 4: *Outcome summary for team 3*

Step	Phase	Outcome
1	*Application Scenario*	Ecological Transportation: the individual choice of transportation means impacts personal and environmental conditions.
2	*Problem Definition*	Traffic jams and time spent in vehicles is too high, ecological consequences are a threat.
3	*Theoretical Framework*	Gamified route planning motivates people to plan more eco-friendly and less time consuming travel routes, as gamification can reinforce behavioural change
4	*Game Element Selection*	Choices gives user control, Rewards give positive feedback, Avatars increase identification, Community fosters collaboration but also competition, Challenges require effort and give a sense of value of achievement
5	*Implemented Prototype*	Gamified navigation assistance app with an own garden that changes its growth and health status according to own transportation behaviour. Tracking of users choice of transportation means and planning behaviour. Fig. 6a-6c show impressions from the resulting prototype.
6	*Evaluation Plan*	Evaluation based on time spend in the app, routes planned using the app, data collected on actual mobility behaviour



(a) *Route Planning* **(b)** *Shop* **(c)** *Garden*

Figure 6: *Screen-shots project prototype "Garden Green" (team 3)*

Table 5: *Outcome summary for team 4*

Step	Phase	Outcome
1	*Application Scenario*	Juggling Training: being able to juggle can have positive health effects.
2	*Problem Definition*	The cognitive and psycho-motor requirements to train juggling are very high for adult learners. Training juggling however is hard, requires space and materials.
3	*Theoretical Framework*	Reducing impact of cognitive and psycho-motor requirements by influencing spatial and temporal aspects of juggling in immersive environment (VR)

Outcome summary (cont. table 5)

Step	Phase	Outcome
4	*Game Element Selection*	Virtual Path visualise optimal behaviourVirtual Mirror allow to visualise and control own behaviourTime Dilation allow to stretch time in VRContextual Information to assist player in understaning the taskInteractive virtual objects offer a variety of playful training modesHaptic feedback improve learning in virtual environmentUI stats give feedback on learning progress and achievements
5	*Implemented Prototype*	sensor-based virtual reality training game as a virtual circus in which a learner can learn to juggle with a variety of different objects, which behave differently in spatial and temporal aspects due to form, weight, material. Fig. 7a-7b show impressions from the resulting prototype.
6	*Evaluation Plan*	Evaluation based on data collected in the application (time spent, performance measures) complemented by evaluation on transfer of juggling performance improvement into real world juggling

(a) *Start Screen* **(b)** *VR Demo*

Figure 7: *Screen-shot and demo of project prototypes "Juggling Tutor" (team 4)*

At the end of the course we included a feedback and evaluation session with the students to assess their understanding of the GaDeP framework, their satisfaction with the method and their outcomes and to gather additional feedback from them. This session was organised as a focus group discussion to gather qualitative feedback on the method and its applicability. All fifteen students were present in this final session.

Students reported, that they initially thought, GaDeP had a high learning curve and required a high cognitive effort to get acquainted with it. They also mentioned, that for a course of only six weeks, the method imposes too many different and challenging steps. However, all teams were confident, that the outcome of their game prototypes has gained a lot from applying GaDeP, as the approach improved their theoretical understanding of the problem they aimed to address while it likewise guided them towards designing a practical application based on the theoretical background.

In addition to the feedback gathered from the participants, the authors of this article assessed the submitted team outcomes according to their correct application of the framework. This has been done by reviewing the delivered outcomes for each phase (Is the application scenario well described? Is the identified problem justified? Are the scientific theories selected relevant to the problem? Was the selection of game elements appropriately justified with the selected theories? Could the game elements be designed and implemented appropriately? Is the evaluation procedure described according to the theories selected and will it help to understand the impact of the developed application?)

According to that, all four teams were able to apply the GaDeP framework appropriately. As shown in tables 2-5, all four teams completed all six stages of the GaDeP framework. Each team has chosen a different application scenario (ranging from supporting concrete learning goals such as driver license training to more behavioural change oriented scenarios on societal level such as fighting global warming) and analysed a problem description accordingly.

Apparently, the distinction of theoretical framework and game element selection was harder to understand and realise: one of the four groups mixed these two phases and already in the theoretical framework defined game elements. The other three groups kept these steps clearly separate. Especially within these two phases the high-level nature of GaDeP becomes apparent: the selection of an appropriate theoretical framework requires to find matching approaches within literature, that address the identified problem at hand. Transferring this concept into a design requires the application of design methods.

The design and implementation phase was naturally easier to understand for students with game design background. All four groups described their prototype concept, created visual artwork and delivered an initial functional prototype. However, it has to be stated, that this step requires further attention, if GaDeP is to be applied by people without any game design background.

As the time span of this six-week course was too short to let the student teams perform an evaluation with real users, none of the four teams applied their prototypes to external end users. However, at the final presentation day, all teams demonstrated their prototypes to the lecturers and a group of additional researchers visiting the session. Additionally, all groups managed to describe an evaluation concept.

7 Conclusions and Future Work

The key contribution of this article is the application and validation of GaDeP as a design framework for the creation of gamified applications independent of the application domains. To substantiate this claim, we followed a two-fold validation approach that delivered the insights described in the following to sections.

7.1 GaDeP and Gamifire

With the implementation of Gamifire as reference infrastructure for GaDeP, we were able to show that it is possible to deliver a "scalable, platform-independent, cloud-based Infrastructure for meaningful gamification of MOOC" (RQ1). We were able to meet the requirements collected for such a platform and to apply and test Gamifire in several application cases.

Addressing RQ3, we were able to explore the flexibility of Gamifire to support different educational MOOCs following different educational settings.

However, with respect to RQ2 and as we have seen from our application cases, the implementation and application of Gamifire faces a number of trade-offs, which show, that some conceptual issues have to be addressed in future work: (1) The solution found addressing the trade-off between platform-independence and meaningful gamification as highlighted in section 4.3 requires to be re-thought, in order to get rid of erroneous extra work. (2) The conflicts found between some of the game elements requires us to offer more guidance to designers of MOOCs and gamification in order to share a clearer understanding of which game elements combine well for which gamification goals. To achieve this, more research on the effects of specific game element configurations needs to be performed. Gamification remains a process requiring well-defined procedures and concepts. We hope, that Gamifire based on the methodology presented contributes to a better understanding and application of meaningful gamification in online learning.

7.2 GaDeP beyond MOOC

As has been shown in the study reported in section 6, the applicability of GaDeP goes beyond the MOOC context. This shows the general potential of GaDeP as a context independent framework for the design of gamification. Addressing RQ4, the variety of the different approaches delivered confirms that GaDeP is by no means limited to MOOC and can be applied to various application scenarios.

Furthermore, reporting our experience with the application of GaDeP by student team as part of their course assignment, it has been demonstrated, that the framework can be handled in a rather short period of time: during a six-week course, with just one weekly lecture, student teams were able to get through all phases of the framework and to deliver appropriate outcomes. This generally confirms, that GaDeP is comprehensible and applicable by designers and developers independent of the inventors of GaDeP (RQ5). However, we have to state, that the students received some additional support to cope with the limited amount of time (see section 6).

A limiting factor to the use of GaDeP was the high initial learning curve. This learning curve was partially due to the high-level nature of GaDeP, which does not prescribe low-level counterparts for each of GaDeP's phases. As reported in section 6, this imposed difficulties especially in phase 3 (theoretical framework) and phase 4 (game element selection) of GaDeP, where participants struggled most with the application of the step and where most support was needed. Examples for such counterparts are e.g. the collection of game design patterns of [5], that can be used in phase 4 of GaDeP (game element selection).

Also, the empirical evaluation of gamified solutions developed according to GaDeP is currently limited to cases within the MOOC field, addressing goal achievement, engagement, social presence. To address these two issues, we aim at doing followup research in the following directions:

1. *Further target groups.* To overcome the issue, that GaDeP so far has been applied by experts and additional people with game design background, we aim at inviting further participants with a humanistic background to use GaDeP for the conceptualization of their gamified approach. This enables us to verify if the GaDeP can be understood on short-term also by non-game designers.

2. *Best practice collection.* The high-level nature of GaDeP causes a gap in the applicability of each step to identify and perform appropriate steps. To overcome this problem, we want to collect, document, and systematise best practice examples about the use of GaDeP and its application in additional application scenarios and problem areas. Well-documented best practice examples aim at flattening the initial learning curve. As a first step towards this, we aim for upcoming semesters at also using the (reviewed and anonymized) outcomes of this course as input to be able to give a growing collection of examples.

3. *Framework linking.* Another step towards better supporting the applicability of GaDeP we want to better link GaDeP to other existing frameworks, which complement the GaDeP high-level framework with low-level processes to instantiate the different steps of GaDeP. An example for such a framework is the game design pattern collection [5]

as mentioned above. But also specific frameworks for problem definitions, evaluation frameworks, and design frameworks as well as technological platforms have to be considered. Examples for such frameworks have been presented in [17, 24, 27].

4. *Extended application fields.* Perform additional evaluations of gamified solutions designed and implemented following GaDeP. In line with this strategy we are currently specifically exploring additional use cases in the psycho-motor domain, where GaDeP and the WEKIT framework complement each other. One of our current targets is to combine GaDeP and the WEKIT framework on the methodological level and to explore the integration of Gamifire with a framework for multimodal interaction [34–37]. With this move we aim to explore the systematic application and evaluation of gamification in this domain. A first step in this direction has been performed by team 4 (juggling tutor) to complement game elements with instructional design elements in the psycho-motor domain.

With these directions in mind it is our vision to move towards a generally understandable and applicable framework for the design and implementation of meaningful gamification.

Acknowledgements and Ethics.

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