Boss fights in lectures! – A longitudinal study on a gamified application for testing factual knowledge

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Abstract. Gamification is used to influence the motivation and behavior of users. In research, the effect of gamification on motivation and other psychological outcomes has been confirmed in various application contexts. Gamification critics state that a sustained success is unlikely, because of the implementation of extrinsic motivation drivers like rewards. Current studies, however, have shown that gamification possesses the potential to support intrinsic motivation. In this article, we introduce a gamified app for testing factual knowledge, which we developed based on current empirical findings and recommendations and analyzed in a longitudinal study for novelty effects. In contrast to other contributions, our app takes up the boss fight concept to support a gameful framing and uses various game elements to provide feedback to students in lectures. Overall, students evaluated the app to be very useful and fun, and additionally reported positive outcomes concerning the experiences of autonomy and competence.

Keywords: Gamification, Education, Motivation, Design Science Research, DSR, Self-Determination Theory, SDT, MDA Framework

1 Introduction and background

Gamification refers to the use of game elements in a non-game context [2] and is commonly used in app development to increase the motivation and engagement of users and provide a gameful experience [7]. In the past, many short-term studies have proven the motivational effect of gamification in different – mostly educational – application scenarios [4]. The longitudinal study by Hanus and Fox, however showed a negative outcome when using gamification in the classroom [5]. Since then, the share of publications studying the long-term effects of gamification has grown, but it remains scarce compared to cross-sectional studies. Yet, recent studies for example by Mekler et al. [10], Lieberoth [9], Forde et al. [3] or Sailer et al. [16] suggest that gamification can also support intrinsic and thus long-term motivation [15].

The past two years, we used the published knowledge of the gamification community to develop a gamified application for testing factual knowledge in lectures. We chose the educational context on the one hand, because a lot of literature in this context provides recommendations to build a successful application. On the other hand, it allows us to collect large amounts of data from field experiments in our lectures, as the students are usually quite interested and critical, when it comes to innovative teaching formats. Ultimately, however, the research project is not intended to serve an end in itself, but should rather provide a meaningful utilization of gamification, which both students and lecturers can benefit from.

That is why, in contrast to many other gamification projects, we started to identify requirements for our app and founded them on current literature regarding motivational theory and game design models, to follow the design science research approach for information systems [13]. We did not follow the one-size-fits-all approach [9, 12] by simply adding *points*, *badges* and *leaderboards*, but instead picked up a well-known concept from role play games: the boss fight – a particularly challenging type of *quest*, where players need to overcome a boss character. To support this concept, we framed the activity with a *gameful narrative* to foster an actual game-like perception and thus increase enjoyment [9]. Additionally, players got to pick an *avatar*, which represents them during the boss fight [16]. The app provides evaluative and comparative feedback to be informational, but not controlling [3]. Furthermore, the new concept is based on both *collaboration* and *competition* and picks up different features from existing gamified learning apps such as *Classcraft, Kahoot!* or *Quizizz*. However, compared to other systems, our app provides the functionality of deactivating game mechanics, to analyze individual effects of chosen design elements, which we will do in future research. To sum up, the gamified app helps lecturers to do fully customizable gameful question sessions to test factual knowledge, where students collaboratively quiz against a virtual boss in a narrative setting to receive individual feedback. This way, we want to contribute to the current research on the goal-oriented use of gamification.

In order to confirm the motivational effect of our app empirically, we evaluated it. However, instead of measuring the difference to a similar "non-gamified" application, which has already been done throughout various gamification studies [4], we chose to study the long-term effect of using our gamified knowledge testing app in lectures. By doing so, we first want to contribute to closing the current research gap of longitudinal studies and second want to find out whether the phenomenon of novelty effects stated by Koivisto and Hamari [8] also applies to our case study in the educational domain. Thus, we want to share our insights to the following two research questions:

- **RQ1**: How to design a gamified application for testing factual knowledge in lectures to foster student’s motivation?
- **RQ2**: How do students evaluate the use of the gamified application after first-time and long-term usage?

To answer the questions, we first briefly introduce the research design and methodology of our research project. Then, we will describe the prototype artifact considering the identified requirements and the resulting design. After describing the artifact, we present the results of our first-time and long-term usage evaluation and compare them by doing a statistical mean value comparison. Furthermore, we will discuss the significant differences between the two groups and interpret the results regarding the effectiveness of our gamified app. In the end, we will summarize our findings and underlying limitations in a short conclusion and provide a short outlook of our future research endeavors.

2 Research design

In order to address the research questions, we used a mixed-method approach in the manner of the Design Science Research Method (DSRM) according to Peffers et al. [13]. This problem-oriented approach describes a structured procedure in the field of information systems and behavioral science to generate knowledge. In particular, the method includes the well-founded development of IT artifacts and their evaluation in order to solve the identified problems. In our research design, we pursued the following research process (see Fig. 1).

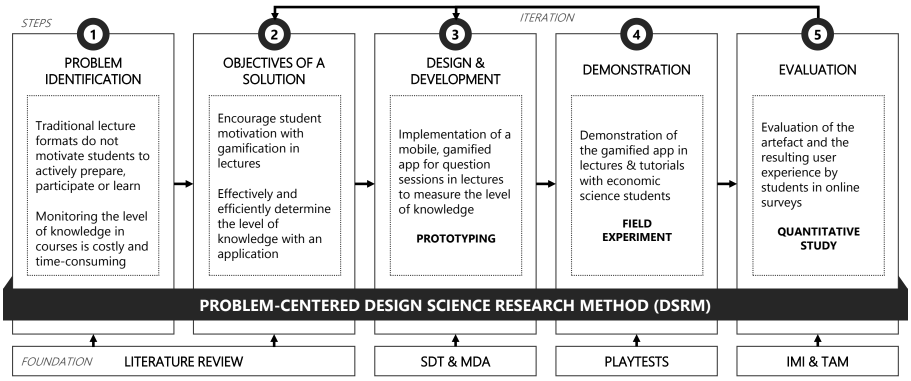

Fig. 1. DSRM Process Model

First, we identified the problem based on academic literature (Step 1). Then, we used current findings from gamification research in education to derive the requirements for a gamified application for testing factual knowledge (Step 2). Subsequently, the derived prototype artifact was implemented based the concepts of Self-Determination Theory (SDT) [15] and the MDA framework [6] (Step 3). The demo took place in multiple questions sessions (each 3 min. long) throughout different playtesting periods (Step 4). We tested the app with economic science students who attended our lectures or tutorials (see Table 1). In the winter term, we demonstrated the app in four different lectures and asked the students to evaluate their first-time user experience in a short survey (Step 5). In the summer term, we regularly used the app in our tutorials after completing a large topic and conducted the survey after the third use at the end of the semester. The online survey included items from the Technology Acceptance Model (TAM) [18] to measure acceptance and the Intrinsic Motivation Inventory (IMI) [1] to measure motivational effects of the artifact. To analyze for novelty effects of gamification, we did a mean comparison of the data collected from the two usage groups (first-time vs. long-term).

Table 1. Numbers of participants in gamified question sessions during the field experiments

Term	Use	SESS	Type	Playtesting Period	PART	SURV	Gr.
Winter	1st	4	Lectures	18.12.18 – 25.01.19	209*	**153**	a
Summer	1st	15	Tutorials	21.05.19 – 25.05.19	264	/	/
	2nd	15	Tutorials	24.06.19 – 28.06.19	183	/	/
	3rd	4	Tutorials	16.07.19 – 21.07.19	93*	**65**	b

Note. SESS: Number of Sessions; PART: Number of Participants; SURV: Completed Surveys; Gr: Comparison groups

3 Artifact description

3.1 Requirements

For a structured approach in system development, we identified the requirements for a gamified application for testing factual knowledge in the lecture context and founded them with scientific literature. We have differentiated these requirements in four categories: (1) contextual, (2) motivational, (3) game and (4) research-based requirements.

Contextual requirements. The application case foresees that lecturers prepare questions, which are answered by the students (R_{C1}). In order for the lecture to be scheduled, it should also be possible to schedule the sessions accordingly (R_{C2}). In principle, it should be as easy as possible to test as much knowledge as possible in a short time (R_{C3}). The questions should be evaluated automatically and directly after the question session to provide users with instant feedback (R_{C4}). Students should receive individual feedback on their answers in order to benefit from active participation (R_{C5}). Moreover, the lecturer should be provided with aggregated data on the proficiency of the students so that possible gaps in knowledge can be addressed specifically in the lecture (R_{C6}).

Motivational requirements. In current literature, particularly *Self-Determination* and *Cognitive Evaluation Theory* explain motivational effects of gamification [14]. Therefore, current study results and theory-based assumptions should be integrated in the system development process. From the perspective of learning psychology, intrinsic motivation (resulting from the inherent interest in an activity) seems to be valuable in education. According to SDT, the basic psychological needs for *competence*, *autonomy* and social *relatedness* are considered as prerequisites for intrinsic motivation [15]. To ensure that these three needs are satisfied by a gamified app, three motivational requirements arise: First, using the app is voluntary [5, 12] and anonymous to support students' experience of autonomy and to inhibit the feeling of an examination situation (R_{M1}). Second, the app needs to provide informative (non-controlling) and meaningful feedback to strengthen the users' experience of competence (R_{M2}) [3, 15]. Third, the app needs to support group activities to strengthen feelings of social relatedness (R_{M3}) [15].

Game requirements. The motivational effect of Gamification is determined by the implemented game design elements. Thus, current study results should be considered in the implementation of the different elements. On the one hand, the different preferences of the users need to be considered (R_{G1}). Different user type or player trait models assume that users have different preferences with regard to the implemented design elements (e. g. *socializers* prefer collaboration over competition) [17]. According to the MDA framework [6], which categorizes game elements into *mechanics*, *dynamics* and *aesthetics*, users decide to play a game based on the emerging aesthetic (kind of fun, e.g. *challenge*), that result from the implemented mechanics. Therefore, to address a broad audience, the gamified app should pick up different mechanics (R_{G2}) [11]. Moreover, a variety elements could also help to satisfy different psychological needs (e. g. *badges* for competence, *avatars* for autonomy & *teams* for relatedness), as empirical studies suggest [10, 16]. Furthermore, a gameful frame should be created because the app's perception as an actual game supports enjoyment and thus motivation (R_{G3}) [9].

Research-based requirements. In order to address the current gaps in gamification research, the prototype needs to be able to address the motivational effects of individual game design elements [16]. Thus, options to deactivate mechanics become mandatory (R_{R1}). Another constraint of many studies is the use of self-reported data from surveys. Objective measurements, e.g. with regard to performance, need to be done to give more precise and rigorous statements on motivational effects (R_{R2}). Combining self-reported and objective data (e.g. question answers), for example, could show comprehensibly to what extent a poor rank on a leaderboard might mitigate motivational effects. Furthermore, the gamified app should not be evaluated directly after the first use in order to avoid possible novelty effects [4]. Therefore, a regular use of the application in the field should be considered in order to focus on the long-term impact of gamification (R_{R3}).

3.2 Design

The gamified knowledge testing in lectures is based on a responsive web application that provides ubiquitous access, does not require user-side installation, and supports various mobile devices such as smartphones, tablets, and laptops. Lecturers can use an authoring tool to create single and multiple-choice questions on lecture content and thus prepare sessions ($\rightarrow R_{C1}$). The maximum character length per question is limited, as students will have only limited time to answer the questions during the session ($\rightarrow R_{C2}$). Questions already existing from previous sessions can be imported ($\rightarrow R_{R3}$). The question sessions can also be individually customized with regard to duration, difficulty and the feedback elements displayed (e.g. badges or rankings) ($\rightarrow R_{R1}$ & R_{G1}). In the lecture, students can anonymously join the gamified question session without a login procedure via an automatically generated QR code, short link or session number ($\rightarrow R_{M1}$). This way, the lecturer only knows how many students have joined the session, but not who.

At the start, the question session is contextualized by a *story* ($\rightarrow R_{G3}$) of a fictitious comic like medieval setting in which the students are to act as knights. The students have the choice between two *avatars* ($\rightarrow R_{G2}$) to represent during the sessions: Attacker or defender. The avatars differ in their characteristics. Attackers have less life, but can cause more damage per correct answer. Defenders are the more risk-averse option and therefore have more lives to allow for some mistakes. This way, students can choose an individual, meaningful play style based on their own estimated level of knowledge ($\rightarrow R_{G1}$), which also supports the experience of autonomy ($\rightarrow R_{M1}$).

After character selection, the lecturer can start the question session in quiz format ($\rightarrow R_{C3}$). The students will then receive randomized questions from the prepared question pool on their mobile device within a set time limit ($\rightarrow R_{C2}$). For each question, 30 seconds are available to select and confirm one or more answers from the four possible answers ($\rightarrow R_{C3}$). After confirming, there is direct feedback on the question by flashing either red (wrong answer) or green (correct answer) and updating the current winning streak correspondingly ($\rightarrow R_{C5}$ & R_{M2}). Then, the next question is given out and the 30 second timer resets. For each correct answer, the participants receive *points*, which can be increased through quick responses, low error rates or winning streaks ($\rightarrow R_{G2}$ & R_{M2}). The final score determines the user's placement on the *leaderboard* ($\rightarrow R_{G2}$).

Moreover, the question sessions take up the *boss fight* game concept as a challenging *quest* mechanic (→$R_{G2,3}$). All participating students (or knights) collaboratively quiz as a group against the question pool of the lecturer, which is visualized as a boss character (a dragon) with a life bar (→R_{M3}). Each correct answer takes life points from the boss. However, if the answer is wrong, the students lose one life. In order to win the boss fight, the students must correctly answer a minimum number of questions in time. The system calculates the required quantity based on the participants and the lecturer's set duration and level of difficulty. If the time runs out or all students are eliminated, the boss fight is lost (→R_{G3}). Overall, the boss fight is displayed on the lecturer's screen, so that eliminated students, can continue to follow the group activity and possibly help their fellow students (→R_{M3}).

At the end of the question session, the students are assigned a pseudonym (→R_{M1}) and receive individual feedback, which are their *points*, *ranking* as well as up to three *badges* for their greatest achievements during the session (→R_{C5}, R_{M2} & R_{G2}). The badges are collected in different categories, e.g. "winning streak" or "correct answers" and are colored based on difficulty. White badges serve as "consolation prizes", while bronze, silver and gold represent higher *levels* of a category and are therefore harder to reach. To provide a meaningful achievement, only one student per question session can obtain the diamond level “winner” badge (→R_{M2}). Furthermore, the pseudonymised leaderboard and the three best students with their respective results are presented to honor their performance (→R_{M2}). In addition to the gamified feedback, students receive the solutions for their individual questions, while lecturers receive aggregated results of the question session (→$R_{C4,5}$). In addition, statistical diagrams and *performance graphs* are provided for lecturers to determine the level of proficiency (→R_{C6}).

Overall, the different requirements lead to 15 key functionalities. Fig. 2 summarizes how most functionalities resulted from multiple requirements. Moreover, it shows how complex the design and development of a gamified learning app is. Therefore, to assure a comprehending artifact design communication, we share prepared screenshots of the functionalities with their respective requirements in the online appendix.

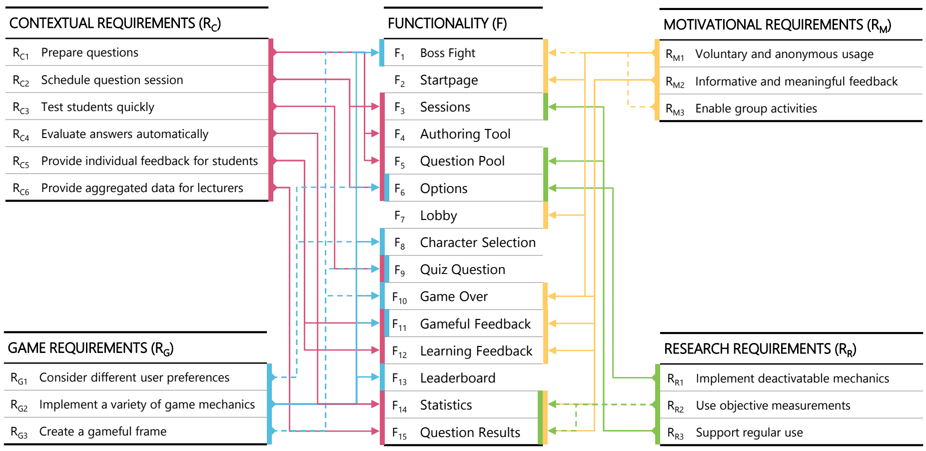

Fig. 2. Implementation of requirements in key functionalities

4 Results from evaluation

Due to our trend study design, we did an independent-samples t-test with a 95 % confidence interval to compare the means of the survey results from the first-time use (group a; n = 153) with the results of the long-term use (group b; n = 65). The answers were based on a 7-point Likert scale [*completely disagree* (1) to *completely agree* (7)]. In advance, we did a Levene's test to check for equal variances for the different items.

The overall concept of the gamified app for knowledge testing receives a good (2) to very good (1) rating from respondents in both groups (M_a = 1.59; M_b = 1.89). The perceived usefulness (M_a = 6.1; M_b = 5.4) and the intention to use (M_a = 6.1; M_b = 5.6) are also high. However, this result also shows that there is a significant difference between the two groups [t(216) = 4.407, p < .001)]. While the perceived usefulness as well as the intention to use decrease after long-term usage, the low feeling of control (M_a = 2.01; M_b = 2.58) increases significantly [t(216) = -2.99, p = .003]. Nevertheless, both groups perceived participation in the questions sessions as voluntary (M_a = 6.61; M_b = 6.27), even though a significant difference between first-time and long-term usage [t(216) = 2.46, p = .014] was measured. Overall, it is not possible to confirm a negative effect of the gamified application on the *experience of autonomy*.

Regarding the *experience of competence*, however, the gamified application shows a mixed result. Though the students mostly agree (M_a = 5.61; M_b = 5.30) that the results of the boss fight are informative, they were marginally satisfied (M_a = 4.10; M_b = 4.43) with their own performance during the question session. One reason for this finding could be the implemented leaderboard, which ranks all students based on their achieved score. Thus, we additionally did a mean value comparison with two groups based on the students' ranking, which the app tracked during the question sessions of the long-term usage group (n = 65). The ranking is based on the points the students received for correct answers and was linked to the survey answers. As a result, the Top 10 students of the leaderboard, reported a significantly [t(63) = -2,495, p = .015] higher satisfaction with regard to their performance (n = 31; $M_{R<10}$ = 4.94) than students who were ranked worse (n = 34; $M_{R>=10}$ = 3.97). Additionally, we could not determine any other effect of the leaderboard within the scope of this survey. Interestingly, this means the placement had no significant [t(63) = -0.502, p = .618] effect on enjoyment ($M_{<10}$ = 5.92; $M_{>=10}$ = 6.04). However, we were able to measure a significant difference in enjoyment between the first-time (M_a = 6.333) and long-term use (M_b = 5.954), which decreased over time [t(216) = 2.723, p = .007].

Table 2 and 3 show the results from our two independent-samples t-tests, which we carried out in IBM SPSS Statistics 26.

Table 2. Results of independent-samples t-test for high (>=10) and low (<10) rankings

Construct	Item	**M** (SD) *high*	*low*	**Sig.** (2-tail.)	**Difference 95 % CI**
Competence (IMI) [1]	I am satisfied with my performance during the boss fight.	**3.97** (1.33)	**4.94** (1.76)	.015*	[-1.738,-.192]
Enjoyment (IMI) [1]	I enjoyed the boss fight.	**5.79** (1.00)	**6.13** (0.84)	.154 ns	[-.799, .129]

*Note. IMI: Intrinsic Motivation Inventory; M: Mean; SD: Standard Deviation.; CI: Confidence Interval; *: p ≤ 0.05;*

Table 3. Results of independent-samples t-test for first-time (a) and long-term (b) use

Construct	Item	**M** (SD) *a*	*b*	**Sig.** (2-tail.)	**Difference 95 % CI**
Usefulness (TAM) [18]	I think the app is useful.	**6.167** (1.00)	**5.492** (1.10)	.000***	[.372, .976]
Intention (TAM) [18]	I would use the app in lectures.	**6.157** (1.22)	**5.662** (1.33)	.009**	[.127, .863]
Perc. Choice (IMI) [1]	I took part in the boss fight because I wanted to.	**6.618** (.99)	**6.277** (0.76)	.014*	[.068, .612]
Perc. Control (IMI) [1]	I felt like I was being controlled during the boss fight.	**2.010** (1.26)	**2.585** (1.36)	.003**	[-.952, -.197]
Competence (IMI) [1]	I am satisfied with my performance during the boss fight.	**4.108** (2.05)	**4.431** (1.61)	.218 ns	[-.838, .192]
Competence (IMI) [1]	I find the results of the boss fight informative.	**5.618** (1.45)	**5.308** (1.14)	.128 ns	[-.090, .709]
Enjoyment (IMI) [1]	I enjoyed the boss fight.	**6.333** (0.94)	**5.954** (.94)	.007**	[.104, .654]
Rating 1: very good ↔ 5: poor	How do you rate the overall concept of the gamified app?	**1.59** (.59)	**1.89** (.64)	.001***	[-.488, -.120.]

*Note. a: first-time use; b: long-term use; IMI: Intrinsic Motivation Inventory; TAM: Technology Acceptance Model; M: Mean; SD: Standard Deviation.; CI: Confidence Interval; ***: p ≤ 0.001; **: p ≤ 0.01; *: p ≤ 0.05; ns: p > 0.05*

5 Discussion and future research

From the perspective of acceptance according to TAM [18], the students regard the gamified app for knowledge testing as useful and intend to use it in future. Thus, the basic prerequisite for successful use of the app is given. In addition, the study provides insights on the gamified app's positive influence on the motivation of students, as the self-reported behavior based on IMI [1] indicates *enjoyment* (as indicator for *intrinsic motivation*), high *perceived choice* and low *perceived control* (as indicators for feeling of *autonomy*) as well as feelings of *competence*. The cause for motivational effects and the underlying limitations need to be discussed, to determine the role of gamification.

First, with regard to autonomy, the students *wanted* to take part in the gamified question sessions and thus participate voluntarily. Moreover, our case shows that the students do not feel that they are in a control or examination situation, even though this is actually the case. One might argue though whether the voluntary participation was based on gamification and it needs to be taken with a grain of salt that we cannot prove it with certainty. However, from our personal observations and experience using different non-gamified tools, the gamified app was the most successful so far, which is why we will continue analyzing this aspect in our future studies. Nevertheless, we were able to show that the gamified app supports the students' experience of autonomy during question sessions.

Second, with regard to experiencing competence, the use of the app showed positive effects, since the students perceive the app as informative and helpful. However, in case of performance feedback, the app might act as a double-edged sword, due to the integrated leaderboard. We found that students who ranked higher in the leaderboard (in the Top 10) significantly felt more competent. In contrast, students with lower ranking reported less experience of competence. This partly proves Hanus and Fox' suggestion of a negative outcome from leaderboards [5], as the rank was especially highlighted in our gameful feedback. In our case, however, a bad performance can also be associated with the elimination in the boss fight. Therefore, the motivational impact of the leaderboard will need further investigation.

Third, with regard to enjoyment, the students reported that they had fun using the gamified app. A rather lively atmosphere in the lecture and the fact that this enjoyment did not result from their performance lets us assume that students actually felt an inherent pleasure during the activity. In combination with the reported experience of autonomy and competence we conclude that students were self-determined and thus intrinsically motivated [1, 15] to participate in and (hopefully) learn from our question sessions.

Fourth, the results of our study allow a short interpretation regarding the long-term effect of gamification. In particular, the significant decrease of the measured items between the first-time and long-term usage group can be considered as an indicator for a novelty effect, as already suspected in the literature [4, 8]. Even though in both groups the evaluation of the gamified application was positive, the effect was already mitigated after a few months of regular use. We therefore suggest to study whether implementing new gameful features on a regular basis helps to take advantage of the novelty effect. We will address this question for example by adding other game modes to our app.

In conclusion, our project showed how a literature-based concept for a gamified app to test factual knowledge was successfully realized and led to positive motivational outcomes – even though the effectivity decreased due to the proposed novelty effect. However, our results underlie some limitations, which do not allow generalization. Our biggest constraint is that mostly freshmen students of economics were involved in our case, who might be more competitive in general. It still needs to be determined to what extent the application will appeal to others. Therefore, we plan to do comparative field studies with other faculties in the future. In terms of our experimental app design, we will focus on analyzing motivational effects of individual mechanics, as it will help to design successful, personalized and goal-oriented gamified applications. In the future we will also consider social relatedness [15] and current user type approaches [17], as we haven't yet covered these aspects of motivation. As of right now, we will be able to investigate the motivational fabric by deactivating *points, badges, leaderboards* as well as *avatars, quests, story* and *teams* – hopefully by not harming a gameful experience…

Online appendix

In-app screenshots: https://owncloud.gwdg.de/index.php/s/o1ifGN80ttoeqJz

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