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Angaben zur Veröffentlichung / Publication details:

Sailer, Michael, and Maximilian Sailer. 2021. "Gamification of in class activities in flipped classroom lectures." *British Journal of Educational Technology* 52 (1): 75–90. https://doi.org/10.1111/bjet.12948.

British Journal of Educational Technology *Vol 52 No 1 2021* 75–90
doi:10.1111/bjet.12948

Gamification of in-class activities in flipped classroom lectures

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Abstract

For higher education, the question of how in-class activities can be supported in large lectures is of great relevance. This paper suggests a gamified flipped classroom approach to address this challenge. In an experimental study, $N = 205$ educational science students performed either gamified in-class activities using a gamified quiz with points and a team leaderboard, or non-gamified in-class activities using exercise sheets. In line with the theory of gamified learning, the results show a positive indirect effect of gamification on application-oriented knowledge that is mediated by learning process performance. Furthermore, based on a self-determination theory framework, the results show positive effects of gamified in-class activities on intrinsic motivation and social relatedness, but no significant effect on competence need satisfaction. The study provides insights into a particular casual construct of game design elements (points and team leaderboards) triggering specific mechanisms (immediate task-level feedback and team competition) affecting a mediator (learning process performance) that in turn affects a learning outcome (application-oriented knowledge).

Introduction

In higher education, teaching in general and lectures with many students in particular are often dominated by the knowledge dissemination provided by the lecturer (Hoffman, 2014). In this model, students might only transfer small parts of the imparted knowledge to their long-term memory (Chi & Wylie, 2014). This processing from short- to long-term memory is an important prerequisite for flexible and sustainable knowledge application. To prepare students for their upcoming challenges in their future careers, flexible and sustainable application-oriented knowledge, that is, the knowledge to identify relevant aspects of problems and the necessary applicable knowledge to solve such problems (Schwaighofer, Bühner, & Fischer, 2016), is of great importance. To successfully acquire knowledge that can be applied to different situations, students have to actively engage with the topics at hand (Cooper & Robinson, 2000). Recent approaches such as the flipped classroom (Lage, Platt, & Treglia, 2000) address that issue by switching the knowledge dissemination phases, which are typically performed in-class, with knowledge application phases, which are typically performed individually out-of-class. Thereby teachers are able to guide and scaffold students' learning processes and provide valuable feedback in class. Nevertheless, there has been very little focus in recent research on how to design in-class sessions to foster motivation and higher level learning activities for students within flipped classrooms. For higher education,

Practitioner Notes

What is already known about this topic

- Flipped classroom approaches in higher education can be effective, but research so far did not provide sufficient answers concerning how in-class activities should be designed to be effective for learning.
- Gamification can be effective to foster motivation and learning, but effects vary depending on different game design elements used.
- Current empirical research on gamification lacks theoretical foundations and methodological rigor.

What this paper adds

- Theory-based investigation of gamification of in-class activities in a flipped classroom within an experimental field study.
- A gamified quiz with points and team leaderboards within a flipped classroom setting can foster learning process performance that in turn facilitates the acquisition of application-oriented knowledge.
- A gamified quiz can foster students' intrinsic motivation and experiences of social relatedness.

Implications for practice and/or policy

- Gamification is a suitable solution for in-class activities in flipped classroom lectures.
- Gamified quizzes can be effective low-threshold solutions for (higher education) teachers.
- The design of gamified quizzes and the choice of questions are crucial as the effects of the gamified quizzes on motivation might vary depending on the difficulty of the quiz.
- Teachers need to ensure sufficient preparation of students within flipped classrooms.

the question of how in-class activities for all students can be supported in large classroom settings is highly relevant. A gamification approach using gamified quizzes within a flipped classroom lecture setting will be introduced and empirically investigated. The goal of the chosen approach is to foster the application of knowledge and the students' motivation.

Flipped classroom

The flipped classroom approach was introduced into higher education by the late 1990s in order to provide more active and diverse lessons for learners, on the one hand, and to boost accessibility to advanced technologies for the learning process on the other (Låg & Saele, 2019). Although flipped classrooms cannot be reduced to a single model, they all share the same conception of the teaching sequence. Usual conventional teaching arrangements consist of an initial face-to-face instruction in-class, followed by individual learning activities out-of-class, normally as homework. In flipped classrooms, this sequence of the learning arrangement is literally *flipped* (Lage *et al.*, 2000): learners start with a self-study phase usually supported by multimedia material in which they acquire knowledge at their own pace. In other words, the direct instruction moves from the group learning space to the individual learning space. Besides the learners' flexibility to choose when and how to engage in out-of-class activities, advocates stress the advantage of the active involvement and application of knowledge during in-class activities (Huang, Hew, & Lo, 2019; O'Flaherty & Phillips, 2015). Even though the benefits of the model are well described in theory, robust evidence on the effectiveness of flipped teaching is hard to find (O'Flaherty &

Phillips, 2015). In fact, the majority of studies on the flipped classroom focus on student perceptions and satisfaction with the teaching format. Regarding learning performance measures, the results of a systematic review and meta-analysis by Låg and Saele (2019) indicate a small effect in favor of the flipped classroom on learning in comparison to traditional teaching. The more recent comprehensive meta-analysis by Strelan, Osborne and Palmer (2020) reports a moderate positive effect on student performance. In this meta-analysis the flipped classroom was beneficial compared to traditional teaching regardless of discipline. However, the reviews on the flipped classroom suggest that more research is needed to validate its efficiency (Lundin, Rensfeldt, Hillman, Lantz-Andersson, & Peterson, 2018; O'Flaherty & Phillips, 2015). Research indicates it would be promising to compare different flipped classroom arrangements, especially focusing on in-class activities, in order to gain more information about how they can be integrated into an overall approach (Tucker, 2012). As a consequence, we want to examine the role of gamification as a resource for in-class activities in flipped classroom settings.

Gamification

The basic idea of gamification is to apply game design elements in non-game contexts (Deterding, Dixon, Khaled, & Nacke, 2011). As the body of research increases, education is one of the central contexts in which gamification has been applied and investigated (Seaborn & Fels, 2015). However, the studies investigating gamification in general and in higher education in particular lack theoretical backgrounds as well as rigorous design and measurement (Dichev & Dicheva, 2017). Even though meta-analytic evidence suggests that gamification has positive effects on learning and motivation (Bai, Hew, & Huang, 2020; Sailer & Homner, 2020), there is still a strong need for gamification research to investigate these effects further. Such studies should include an assessment and analysis of learning processes (Hamari, Koivistor, & Sarsa, 2014), the application of theoretical frameworks (Seaborn & Fels, 2015; Zainuddin, Chu, Shujahat, & Perera, 2020), and methodological rigor (Hamari, 2017), especially in the context of higher education (Huang & Hew, 2018). The present study tries to meet these criteria starting with a solid theoretical framework, which will be introduced in the next section.

Gamification and learning

The theory of gamified learning (Landers, 2014) offers a general framework that conceptualizes the relationship between gamification and learning. This theory consists of four components: (1) instructional content, (2) behaviors and attitudes, (3) game characteristics and (4) learning outcomes. First, the theory proposes that the instructional content directly influences learners' behaviors as well as learning outcomes. Effective instructional content is a prerequisite of successful gamification based on the theory of gamified learning. Gamification is described as a method to improve instruction instead of replacing it (Landers, 2014). Second, the theory hypothesizes that behaviors and attitudes influence learning outcomes. This can happen either directly, or by affecting the relationship between the instructional content and the learning outcomes. Third, game characteristics are expected to directly affect behaviors and attitudes. Importantly, no direct influence of game characteristics on learning outcomes is hypothesized. Gamification affects learning only through an intermediary behavior or attitude (Landers, Bauer, Callan, & Armstrong, 2015). Therefore, introducing game design elements to increase learning can only be effective if the behaviors they elicit are conducive to learning (Landers, 2014).

The theory of gamified learning proposes two ways that gamification can influence learning via behaviors and attitudes. Based on their precise nature, behaviors and attitudes can either *moderate* or *mediate* the relationship between instructional content and learning outcomes (Landers *et al.*, 2015).

In the case of a mediating effect, behaviors directly affect learning outcomes, and therefore, constitute an important part of the causal construct (Landers, 2014). An example would be the use of gamification to scaffold students' learning process performance, which then in turn can affect learning outcomes. This mediation is supposed to be the primary mechanism of gamification affecting learning outcomes (Hamari *et al.*, 2014). We will focus on this primary pathway of mediation and show how gamified quizzes could foster learning process performance, resulting in higher learning gains.

Effects of gamified in-class activities with quizzes on learning

Quizzes are often used as a starting point to implement gamification in teaching and learning settings. In recent years gamified quiz platforms such as *Kahoot!* (https://kahoot.com/), *Quizalize* (https://www.quizalize.com/) and *Quizizz* (https://quizizz.com/) have been increasingly applied in teaching and learning settings. Such platforms usually provide task-level feedback via awarding points for right answers. One advantage of gamified quizzes is to provide such feedback about the task immediately. There is evidence indicating that immediate feedback is likely to be powerful on the task level (Hattie & Timperley, 2007; Kulik & Kulik, 1988). Immediate task-level feedback provided by points in gamified quizzes has a high potential to scaffold learning process performance. Better performance during learning processes can in turn result in better quality of application of knowledge measured as an outcome.

Another feature quiz platforms provide is to allow for competitive or cooperative forms of interaction between learners—usually via leaderboards or team leaderboards. Competitive modes of social interaction are common strategies used within gamification. Even though competition can cause social pressure to increase learners' engagement and can lead to higher levels of participation and learning (Burguillo, 2010), competition is a double-edged sword: On the one hand, competition can be destructive, when succeeding means tearing others down. On the other hand, competition can be constructive when it leads students to aim at improving each other's skills and when it encourages cooperation and mutual support (Rigby & Ryan, 2011). Such constructive forms of competition, which share similarities with *friendly competition* (Zainuddin, Chu, *et al.*, 2020), can occur when competition is augmented with aspects of cooperation. Meta-analytic evidence suggests that combinations of cooperation and competition are likely to be an effective gamification strategy (Sailer & Homner, 2020). The resulting team competition can be implemented by team leaderboards, which can foster cohesion within teams and competition between teams.

Effects of gamified in-class activities with quizzes on intrinsic motivation

The central idea of gamification is to adapt game design elements from games to non-game contexts in order to use the motivational appeal of games for purposes beyond the game itself (Sailer, Hense, Mayr, & Mandl, 2017). The mechanisms behind the motivational appeal of different game design elements can be explained by the self-determination theory, which has been successfully applied to the context of gamification (Mekler, Brühlmann, Tuch, & Opwis, 2017; Sailer *et al.*, 2017). The theory postulates three psychological needs that are central for intrinsic motivation and subsequently for high-quality learning: the need for competence, autonomy and social relatedness (Ryan & Deci, 2000). These three psychological needs are motivational resources that can be satisfied or thwarted through the learning environment (Vansteenkiste & Ryan, 2013). Thus, modifications of the learning environment, which gamification does by definition, can affect psychological need satisfaction (Sailer *et al.*, 2017). In the case of a gamified quiz, the needs for competence and social relatedness are relevant: The psychological need for competence denotes feelings of efficiency and success in interacting with the learning environment (Vansteenkiste & Ryan, 2013). This need can be addressed by providing different types of feedback, for example by using points in gamified quizzes (Rigby & Ryan, 2011). The need for social relatedness refers

to the belonging and attachment to a group and can be addressed by shared goals, for example through a team leaderboard in gamified quizzes (Sailer *et al.*, 2017).

In summary, there is empirical support that points and team leaderboards that are used in quizzes potentially help to satisfy the needs for competence and social relatedness as well as fostering intrinsic motivation (Rigby & Ryan, 2011).

Gamification of the flipped classroom

Based on the above considerations, the gamification of in-class activities in flipped classroom arrangements could be an effective method to foster learning and motivation; though its effectiveness has hardly been investigated in higher education within experimental designs so far. In particularly, robust evidence is missing about the interplay between process and outcome performance in such gamification interventions (Sailer & Homner, 2020).

A review of gamified learning in the context of higher education provided encouraging support for gamification and game-based learning in higher education in general. Most studies included reported benefits to engagement and motivation, though the results concerning students' performance were mixed and inconclusive (Subhash & Cudney, 2018). Furthermore, most of these studies applied game design elements to out-of-class activities, instead of in-class activities, except one study: Yildirim (2017) investigated gamification-based teaching practices within an experimental design and found positive effects of gamified in- and out-of-class activities on students' achievement and attitude toward the lesson. One study not covered by the review also focused on in-class activities in a flipped classroom (Hung, 2018). However, the intervention, which was applied to a university-level language learning setting, should be classified as a digital board game rather than gamification. Nevertheless, the results are promising as the board game helped reduce students' anxiety about speaking and increased students' motivation to engage in in-class activities (Hung, 2018).

A series of further studies investigated game-design elements in flipped classroom settings in higher education. However, all of them gamified out-of-class activities: Results from Huang and Hew (2018) indicated that gamification enhanced students' engagement in out-of-class activities. Another study investigating gamified quizzes in out-of-class activities showed that students who completed the gamified quizzes had significantly better test scores, although this effect did not persist in subsequent tests (Sanchez, Langer, & Kaur, 2020). Aşıksoy (2018) found positive effects of gamified out-of-class activities on motivation and learning achievement. Jo, Jun, and Lim (2018) succeeded in increasing students' preparedness by applying gamification to a flipped classroom. Like the studies from the review above (Subhash & Cudney, 2018), they all focused on out-of-class activities in contrast to our study focusing on in-class activities.

Additionally, there are studies that investigated gamified quizzes within classrooms, but not in flipped classroom settings: One study showed that gamified quizzes can foster students' motivation (Raes *et al.*, 2020). Another study about gamification of in-class activities compared different types of gamified quizzes with paper-based quizzes. The authors concluded that different gamified quizzes are not superior to paper-based quizzes regarding overall learning achievement, but gamified quizzes fostered engagement and fun in the classrooms (Zainuddin, Shujahat, Haruna, & Chu, 2020).

Although not in the context of higher education, two studies that investigated gamified flipped classrooms in schools are worth mentioning: Zainuddin (2018) found a positive effect of gamification on the satisfaction of competence, autonomy and relatedness. Furthermore, he found a positive effect on learning achievement. Lo and Hew (2018) investigated three different teaching

approaches, namely traditional learning, flipped learning with gamification, and online learning with gamification. The gamified flipped classroom outperformed the other approaches, which highlights the high potential of combining gamification and flipped classroom approaches.

In conclusion, there has been much research into gamified learning in higher education in general. However, there is a research gap: namely studies about gamified flipped classroom interventions with a strong theoretical basis that focus on the gamification of in-class activities and consider learning processes.

Research questions

RQ1: To what extent does a gamified quiz with points and a team leaderboard affect learning process performance and application-oriented knowledge in a gamified flipped classroom intervention?

Empirical studies in higher education show promising results regarding the effects of gamification on students' performance. From a theoretical perspective, the theory of gamified learning (Landers, 2014) suggests that gamification can boost learning process performance. The driving mechanism is thought to be immediate task-level feedback (Hattie & Timperley, 2007). Learning process performance in turn is hypothesized to influence application-oriented knowledge measured as a learning outcome. Therefore, the theory hypothesizes an indirect effect of gamification on learning outcomes via learning process performance (Landers, 2014):

H1: There is an indirect effect of a gamified quiz with points and a team leaderboard on application-oriented knowledge, which is mediated by learning process performance.

RQ2: To what extent does a gamified quiz with points and a team leaderboard affect intrinsic motivation and psychological need satisfaction in a gamified flipped classroom intervention?

Empirical studies in the context of higher education provide evidence for gamification positively influencing motivational outcomes (Subhash & Cudney, 2018). Even though psychological need satisfaction has not been the focus of game-related research in higher education so far, there is some evidence that game design elements help to satisfy the needs for competence and relatedness (Sailer *et al.*, 2017; Zainuddin, 2018). Based on the self-determination theory framework, gamification is hypothesized to foster intrinsic motivation and the satisfaction of the needs for competence and social relatedness (Rigby & Ryan, 2011):

H2.1: A gamified quiz with points and a team leaderboard has a positive effect on intrinsic motivation.

H2.2: A gamified quiz with points and a team leaderboard has a positive effect on competence need satisfaction.

H2.3: A gamified quiz with points and a team leaderboard has a positive effect on social relatedness need satisfaction.

Method

Sample and design

To investigate the research questions, we applied an experimental pretest and posttest design. We manipulated the between-subject factor *gamification*. While the gamification group engaged in gamified in-class activities using a gamified quiz, the control group engaged in non-gamified

in-class activities using exercise sheets. $N = 214$ educational science students participated in the study. Students were enrolled in a German university. Participants who did not answer the whole pretest or posttest were excluded from the sample, resulting in a final sample of $N = 205$ participants. The average age of participants from the final sample was 23 years ($M = 22.59$; $SD = 3.18$). About 187 women (91.2%) and 17 men (8.3 %) took part. One participant did not provide any information on gender (0.5 %). The study was part of two lectures in an educational science program and for each lecture participants were randomly assigned to the gamification or control condition. The gamification group consisted of $n = 96$ participants, the control group consisted of $n = 109$ participants.

Procedure and learning material

Regarding the students' out-of-class activities, one week before the study a link was sent to all students with a video lecture and information about the time and place of the upcoming in-class event. In the video, the lecturer gave a talk about feedback and assessment in a medium close-up format. The video lecture covered theories and empirical results about assessment and feedback. The video lecture was 28 minutes long and consisted of 31 downloadable slides. We asked the students to prepare themselves for the upcoming lecture with this material. The lecturer announced that the content would be applied within the next in-class lecture. All in-class events were guided by the same lecturer, who was also the narrator of the video lecture.

Regarding in-class activities, the face-to-face event started with a short pretest (7 minutes) to assess students' *intensity of preparation*, *declarative prior knowledge*, and demographic data. The following in-class event included training questions about assessment and feedback and a debriefing of these questions. The questions referred to the practical application of the video-lecture content and thereby covered the application of theories and empirical findings about feedback and assessment in different educational contexts such as schools, universities and further education. While the students had to work on the training questions in-class individually, the debriefing was guided by the lecturer in a plenary session. Students' *learning process performance* was assessed by tracking students' performance on the training questions. The in-class event lasted 45 minutes. After this, students had to complete a posttest (20 minutes) that included the assessment of situational *psychological need satisfaction*, *intrinsic motivation* and *application-oriented knowledge*.

Manipulation of the independent variable

The manipulation of the independent variable, which is gamification, took place during the in-class activities. The corresponding between-subject factor *gamification* is a dummy coded variable with "0" indicating "non-gamified in-class activities" (control group) and "1" indicating "gamified in-class activities" (gamification group). The out-of-class activities, namely the video lecture, were not gamified.

Non-gamified in-class activities

The control group received an exercise sheet with training questions about assessment and feedback. The format of the questions was single choice with four answer options. Students were asked to complete the questions individually. After completion of the questions, the exercise sheets were collected by the lecturer. During debriefing, the lecturer provided the solution for every question, step by step. Therefore, slides with the questions and the highlighted right answer option were shown to the students. A short explanation was provided for every question.

Gamified in-class activities

The gamification group had to work through the same training questions as the control group, but these questions were implemented on *Quizalize* (https://www.quizalize.com/), a gamified

in-class quiz platform. We set up the quiz with the "show correct answer" option switched off. Students had to visit the *Quizalize* website via a web-connected device and had to enter a code provided by the lecturer to access the quiz. Students received information about how to log in and how the gamified platform works. Participants were randomly assigned to two teams by the system. On the presentation screen a team leaderboard in the form of a ranking, consisting of a summed score of both teams, was shown in real time. We instructed the students to self-create anonymized codes that they used as their names. While answering, the names of the students moved toward the center of the presentation screen indicating their progress in the quiz (see Figure 1).

Students had to work on the questions on their own web-connected device individually. Based on the correctness and answering speed, the students received points for each question (see Figure 2).

These points were added to the corresponding team leaderboard, which was continuously shown on the presentation screen (see Figure 1). The students were able to compare the results of their team to the results of the other team on the presentation screen in real time. Each individual score of the participants was shown below the corresponding team score. The correct answer was not shown if participants chose the wrong one. At the end of the quiz session, the lecturer announced the winning team. After this, the lecturer provided the solution for every question step by step, with similar highlights of the right answer option and the same short explanation for every question as in the control condition.

Measurement of variables

Declarative prior knowledge

Declarative prior knowledge was assessed via two multiple choice questions referring to a crucial aspect for both topics of the lecture, namely assessment and feedback. An example item for feedback is: "What is the difference between knowledge of result (KOR) and knowledge of correct result (KCR) feedback?". The mean of these two items was calculated to create the variable *prior declarative knowledge*.

Figure 1: Presentation screen for the gamification group. Screenshot from Quizalize (https://www.quizalize.com/) [Colour figure can be viewed at wileyonlinelibrary.com]

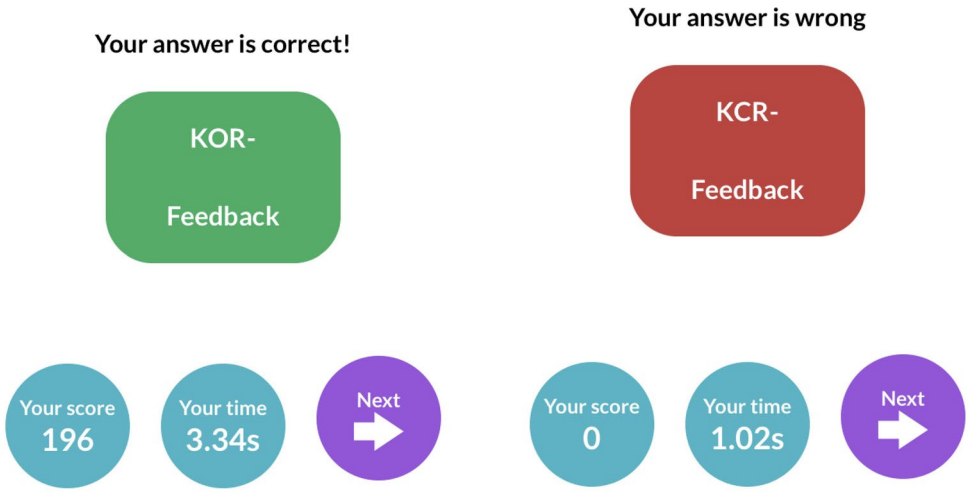

Figure 2: Feedback shown on the students' devices after each question. On the left side is feedback of a student who selected the correct answer (for this question: KOR-Feedback). On the right side is the feedback of a student who selected a wrong answer (for this question: KCR-Feedback). On the bottom are points earned for this question ("your score") and answering speed ("your time"). Screenshot from Quizalize (https://www.quizalize.com/) [Colour figure can be viewed at wileyonlinelibrary.com]

Intensity of preparation

Intensity of preparation was assessed via three items, which covered how often participants watched the video lecture, if participants worked with the slides of the video lecture, and if participants took notes during the video lecture. How many times the video lecture was viewed was assessed via an open question where students entered the number of times they watched the video. The questions referring to slides and notes were assessed as two dichotomous items, with the answer option *yes* rated as the value 1 and *no* rated as the value 0. To assess the variable *intensity of preparation*, a summed score of the above items was calculated.

Learning process performance

Learning process performance was assessed via the multiple choice questions that all participants worked on during the in-class activity. For participants of the control condition, the answers were transcribed from the exercise sheets. For participants of the gamification group, the answers were transcribed from the *Quizalize* results table. The mean of these questions was calculated to create the variable *learning process performance*. Values could range from 0 to 1 and can be interpreted as percentages of right answers provided by the students. An example question was: "A teacher collects the in-class tests. Peter sits in the last row and turns in his test at the very end. Peter therefore had one minute additional time for the test. Which assessment quality criterion is violated?"

Application-oriented knowledge

Application-oriented knowledge was assessed by eight multiple choice questions in an immediate posttest after the in-class activities. The questions covered the application of theories and empirical findings about feedback and assessment in different contexts. The items were assessed in a written test and the mean of these questions was created. Values could range from 0 to 1 and were interpreted as percentages. An example for an application-oriented knowledge question was: "A teacher points out: 'you failed again. You're not a numbers guy'. Which feedback level is addressed?"

Intrinsic motivation and situational satisfaction of psychological needs

All items were assessed on a 7-point-Likert scale. The three items for intrinsic motivation originate from the short scale of intrinsic motivation (Wilde, Bätz, Kovaleva, & Urhahne, 2009). Cronbach's α for intrinsic motivation is $\alpha = .88$. A sample item for intrinsic motivation is "the in-class activities were very interesting." Situational satisfaction of psychological needs was assessed by an instrument of Sailer *et al.* (2017), which is based on and inspired by the intrinsic motivation inventory (Ryan, Mims, & Koestner, 1983). Cronbach's α for competence need satisfaction, which was assessed via four items, is $\alpha = .85$. A sample item for competence need satisfaction is "during in-class activities I had feelings of success." Cronbach's α for relatedness need satisfaction, which was assessed via three items, is $\alpha = .83$. A sample item for relatedness need satisfaction is "during in-class activities I felt emotionally attached to others."

Statistical analysis

We used mediation analysis to investigate Research Question 1. Therefore, we applied the SPSS macro PROCESS Version 3 (model 4). For this analysis, *gamification* was our independent variable (*X*), *application oriented knowledge* was our outcome variable (*Y*), and *learning process performance* was our mediator variable (*M*). We used *declarative prior knowledge* and *intensity of preparation* as control variables for the mediation analysis. We z-transformed all variables before investigating Research Question 1. For motivational learning outcomes (Research Question 2), we used *t* tests to investigate differences between the gamification group and the control group. Hedges' *g* was used to assess effect size. Alpha level was set to 5%, effect sizes were interpreted according to Cohen (1988). We used SPSS Version 24 for the analyses.

Results

Learning outcomes

Table 1 shows the descriptive results for *learning process performance* and *application-oriented knowledge*. For the mediation analysis, we included two control variables: *declarative prior knowledge* and *intensity of preparation*. *Declarative prior knowledge* had significant effects on both *learning process performance*, $b = .21$, $SE = .07$, *95% CI* [.08; .35], and *application-oriented knowledge*, $b = .15$, $SE = .07$, *95% CI* [.02; .28]. *Intensity of preparation* also had significant effects on both *learning process performance*, $b = .17$, $SE = .07$, *95% CI* [.03; .31], and *application-oriented knowledge*, $b = .21$, $SE = .07$, *95% CI* [.07; .35].

Results of the mediation analysis indicate that *gamification* is a significant positive predictor of *learning process performance*, $b = .42$, $SE = .14$, *95% CI* [.14; .70], and that *learning process performance* is a significant positive predictor of *application-oriented knowledge*, $b = .22$, $SE = .07$, *95% CI* [.09; .36]. The significance of the indirect effect was tested using bootstrapping procedures with bias correction for the confidence interval. Unstandardized indirect effects were computed for each of 5000 bootstrapped samples, and the 95% confidence interval was computed

Table 1: Means (M) and standard deviations (SD) of gamification group, control group, and total sample regarding learning and motivational outcomes

	Gamification group M (SD)	*Control group M (SD)*
Learning process performance	.58 (.21)	.47 (.20)
Application-oriented knowledge	.59 (.23)	.60 (.20)
Intrinsic motivation	5.28 (1.21)	4.23 (1.29)
Competence need satisfaction	4.03 (1.29)	4.11 (1.31)
Social relatedness need satisfaction	3.64 (1.49)	2.77 (1.43)

by determining the indirect effects at the 2.5th and 97.5th percentiles. Results support the mediational *Hypothesis 1* that there is a positive indirect effect of *gamification* on *application-oriented knowledge*, which is mediated by *learning process performance*, $b = .10$, $SE = .04$, *95% CI* [.02; .19]. The direct effect of *gamification* on *application-oriented knowledge* was not significant, $b = -.10$, $SE = .14$, *95% CI* [−.38; .16]. Figure 3 shows an overview of the effects investigated within this research question.

Motivational outcomes

An overview of the descriptive results is included in Table 1. Students in the gamification group showed higher *intrinsic motivation* ($M = 5.28$, $SD = 1.21$) than students in the control condition ($M = 4.23$, $SD = 1.53$). The effect of *gamification* on *intrinsic motivation* was significant, $t(202) = 5.36$, $p < .001$, $g = .75$. This is a medium size effect and the result supports *Hypothesis 2.1.*

Regarding *competence need satisfaction*, there was no significant difference between students of the gamification group ($M = 4.03$, $SD = 1.29$) and students of the control group ($M = 4.11$, $SD = 1.31$), $t(202) = -.42$, $p = .67$, $g = -.06$). This result contradicts *Hypothesis 2.2*.

Students in the gamification group felt more socially related ($M = 3.64$, $SD = 1.49$) than students in the control group ($M = 2.77$, $SD = 1.43$). The effect of *gamification* on *social relatedness need satisfaction* was significant and medium-sized, $t(202) = 4.27$, $p < .001$, $g = .60$. This result supports *Hypothesis 2.3.*

Discussion

This study investigated the effects of a gamified flipped classroom intervention on learning and motivation. The gamification intervention consisted of a gamified quiz with points and team leaderboards. In line with the initial hypothesis, gamification had a positive indirect effect on application-oriented knowledge within a flipped classroom intervention. This effect is mediated by the learning process performance of the students. Furthermore, gamification has positive effects on intrinsic motivation and the satisfaction of the need for social relatedness, but no significant effect on competence need satisfaction. Compared to most previous studies in the field, we used a true experimental design. Our results support the theory of gamified learning (Landers, 2014).

The gamified intervention provided the students with immediate task-level feedback. Such feedback mechanisms have been shown to be effective in fostering students' performance during the intervention and allowed for improvements during the learning process (Hattie & Timperley, 2007; Kulik & Kulik, 1988). Even though we found an indirect effect in this study, the direct effect

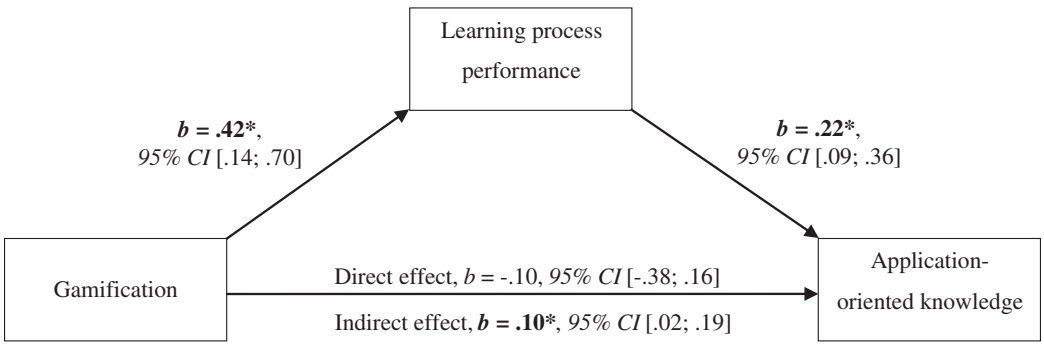

Figure 3: Overview of the effects from mediation analysis. Significant effects are written in bold and marked with an asterisk

of gamification on application-oriented knowledge was not significant. This study shows the importance of focusing on the learning processes involved when investigating gamification, as these can be directly influenced by gamification (Sailer & Homner, 2020). Without consideration of learning process data, gamification did not yield a significant effect on application-oriented knowledge. The missing direct effect of gamification on application-oriented knowledge might be explained by the influence of the flipped classroom arrangement on students' evaluations of teaching in general. Since both groups—control and experimental—were experiencing a new and uncommon teaching approach, which in both groups aimed at students' activation in-class, one can speak of a rather low contrast between the conditions.

Due to the implementation of the study within the curriculum, we had to deal with time constraints that led to a rather short intervention and short instruments with few items, although this implementation of the study within the curriculum has the advantage of high ecological validity. We performed our study in a setting that is identical to day-to-day higher education lectures. Regarding the long-term effects of the intervention, our study does not provide any answers. A long-term implementation was not performed and no delayed posttest has been applied. Concerns of a novelty effect of gamification that have been raised by others (Bai *et al.*, 2020; Sanchez *et al.*, 2020) cannot be ruled out within our study. Studies involving long-term gamification implementations and delayed posttests are needed to further investigate potential novelty effects and the sustainability of learning outcomes (Bai *et al.*, 2020).

Furthermore, the level of preparation had significant effects on learning process performance and application-oriented knowledge. In line with prior research (Gross, Pietri, Anderson, Moyano-Camihort, & Graham, 2015), we found the preparation of students to be a crucial factor for the effectiveness of a flipped classroom. Higher education teachers need to ensure sufficient preparation of students and conceptualize didactically meaningful sessions with high-quality learning assignments and customized video material (Sailer & Figas, 2017). In addition to gamified in-class activities, gamification can also be a possible intervention to facilitate out-of-class activities, and thus, foster the preparation of students (Jo *et al.*, 2018).

Regarding motivational outcomes, we found a significant positive effect of a gamified quiz with points and team leaderboards on intrinsic motivation. This result is in line with research demonstrating gamification having positive effects on motivation within higher education (Sailer & Homner, 2020; Subhash & Cudney, 2018) and prior research involving gamified quizzes in classrooms (Raes *et al.*, 2020). Regarding psychological need satisfaction, results are mixed. Gamification had a significant positive effect on the satisfaction of the need for social relatedness, which is in line with previous studies (Sailer *et al.*, 2017). The team leaderboard, which evoked team competition, might have led to higher social relatedness need satisfaction. Regarding competence need satisfaction, no significant effect of gamification was present, which contradicts our initial hypothesis. This result calls for a more detailed investigation of the feedback processes at work in our study. In the gamification environment, the correct answer was not shown if participants chose a wrong one. Students in the gamification group scored on average 42% of the questions wrong during in-class activities. This means that they in fact received negative feedback (ie, 0 points) in 42% of the questions on average. Negative feedback tends to diminish perceived competence, which can be the case here as the item difficulty was higher than expected (Deci, Ryan, & Williams, 1996). Furthermore, negative feedback can easily be experienced as controlling, a factor that also diminishes competence need satisfaction (Deci et al., 1996). Game design elements and gamified quizzes should be designed in a way that they provide optimal challenges for the students that correspond with their prior knowledge and skills (Zainuddin, Chu *et al.*, 2020). As this is especially relevant for competence need satisfaction, we might have failed to provide

optimal challenges in our study, at least for some students. This result suggests considering not only the level and timing of feedback, but also the direction of feedback in combination with the difficulty of questions used in gamified quizzes.

Our study focused on the mediating pathway of the theory of gamified learning. However, the theory also suggests a moderating effect via attitudes that was not in focus of our study. Future research should also include the role of attitudes, for example, toward learning and toward gamification, to investigate the role of specific attitudes of learners when facing gamification.

Conclusion

The investigated gamification intervention can be described as a low-threshold implementation that can easily be adapted to flipped classrooms within higher education. For practitioners, the following aspects are relevant:

When designing or choosing gamification environments, it is important to identify relevant learning processes that positively predict desired learning outcomes and to implement game design elements that potentially affect these learning processes (Landers, 2014). This study showed that immediate task-level feedback provided by gamified quizzes—as in this case points and the team leaderboard-based intervention—can improve learning process performance. Besides the feedback mechanisms applied, forms of social interaction also have to be taken into consideration. In the present study, we tried to ensure a constructive culture of competition by implementing team competition. This mode of interaction was effective in fostering students' social relatedness.

Furthermore, this study calls for careful analysis of related learning mechanisms—in this case feedback mechanisms. It shows that often neglected aspects like the difficulty of the questions asked within gamified quizzes can affect the impact of the feedback mechanisms used in gamification. The difficulty affects the direction of feedback, which can influence students' experiences such as their feelings of competence (Deci *et al.*, 1996). Our study calls for a careful consideration of item difficulty, and thus, of the optimal challenges for students when designing quizzes (Zainuddin, Chu, *et al.*, 2020).

From a theoretical perspective, the study provided insights into a particular casual construct of game design elements (points and team leaderboards) with specific mechanisms (immediate task-level feedback and team competition) affecting a mediator (learning process performance) that in turn affects a learning outcome (application-oriented knowledge). This contribution is another piece in the puzzle of different paths in various gamification efforts that have to be empirically investigated with rigorous methods (Landers, 2014).

Statements on open data, ethics and conflict of interest

As soon as the review process is finished, the data used for this study will be made available in an anonymized form on an open science framework (https://osf.io/vjcdz/) repository created for this paper.

In our study, we only included data of participants who agreed to a written informed consent. This consent included permission for data collection and evaluation. Furthermore, it emphasized that we assessed the data in a way that anonymized them immediately. Subjects that did not consent to this could participate in the study, but their data was deleted immediately after collection. To avoid disadvantages for individual students (eg, of certain experimental groups), we uploaded the quiz questions as well as the posttest questions to the learning management system right after our

study. Within the following lectures, we included *Quizalize* quizzes in three more lectures during the semester without any experimental variation to offer every student the *Quizalize* experience.

We confirm that neither author has any relationship, financial or otherwise, with individuals or organizations that could influence the work inappropriately. No conflict of interest exists.

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