Impact of Gamified Learning on Learners' Performance: Time and Learning Time Patterns Matter

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Abstract

This study examines the impact of the use of a gamified learning application on the academic performance of 1'600 first-term students in a mandatory introductory course in management at a European University. It aims to contribute to the deeper understanding of the effect of students' learning time and learning patterns using a gamified learning app. We found that increased engagement with the application, measured by time spent and questions answered, is significantly correlated with learning success in form of higher exam scores or grades. Additionally, in line with traditional learning theories, students who used the application more regularly during the semester performed better. Against common expectations, the use of the gamified learning application also correlates with higher scores in the multiple-choice and case study sections of the exam, suggesting that it supports both knowledge acquisition and transferal competences. However, the causality of the effect is critically discussed. With its significant sample size and the measurement of actual learning behavior and learning success, the study contributes to the body of clinical studies.

Keywords: Gamification, Gamified Learning, Learning Apps, Learner Performance, Success Factors of Learning, Learning Goal Taxonomy, Learning Patterns

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1. Introduction

Gamification can commonly defined as the use of game design in non-game settings (Deterding et al., 2011; Robson et al., 2014, 2016) that rewards user behavior (Kim, 2015). It can be employed to drive engagement and motivation in various fields including commerce, exercise, health, marketing, and advertising (Koivisto & Hamari, 2019). Gamification also is a growing trend in learning and education (Robson, 2019; Jaskari & Syrjälä, 2023), employing games or game elements in classes (Dikcius et al., 2021; Humphrey et al., 2021; Fisher et al., 2014), with different types of gamification elements like choose-your-own-adventure story-type platforms (Bechkoff, 2019) or point-based systems (Koppitsch & Meyer, 2022).

Research shows that gamification in educational context can boost both the intrinsic motivation and self-efficacy of students in the classroom (Banfield & Wilkerson, 2014; Ekici, 2021). Students are more motivated to engage with study content and in-class discussions when they act in a competitive learning environment (Ashley, 2019). In addition, student performance in gamified courses can be enhanced compared to non-gamified ones (Dias, 2017; Sarkar et al., 2017; Ekici, 2021). However, while gamification's impact is well documented in many fields, such as management, its application in education is dependent on further research because of the broad variety of different possible contexts, different student groups and learning patterns, types of gamifications, learning goals etc. (Sailer & Homner, 2019; Dichev & Dicheva, 2017; Hamari et al., 2014; Seaborn & Fels, 2015). There is research, for example, regarding the effects of different types of gamification elements (e.g., earning points (Robson, 2019), earning badges (Saxton, 2015), or leaderboards (Barata et al., 2015)). However, the effects of different learning patterns and the effects on different types of learning outcomes still needs further research.

Most existing research is based on smaller student groups, possible also in elective course formats (e.g., Ashley, 2019; Bechkoff, 2019; Koppitsch & Meyer, 2022). But large-scale teaching formats in compulsory courses, where student engagement obviously is a major challenge, still need to be addressed. And many studies base on perceived learning behavior and time use together with perceived study progress (e.g., Revere et al., 2008) with the well-known potential gap between actual compared to intended or perceived behavior (e.g., O'Donovan et al., 2013). This study aims to deepen the understanding of gamified learning by analyzing the usage and outcomes of a gamified learning app. It draws from the theory of gamified learning (Landers, 2015), which stipulates that gamification influences student behavior and attitudes for better learning outcomes, both directly and indirectly. The novelty of this study is on the one hand that it focuses on actual learning rather than perceived learning, which is often used in educational studies (e.g., O'Donovan et al., 2013). Therefore, we focus on grades achieved rather than student self-reports and data on actual time spent using a learning app rather than reported usage. It is also unique because the study was conducted in a large setting. The study is based on a cohort of 1'600 students from a mandatory introductory course in management, which is accompanied by a gamified app. It also looks into the effects of the use of the gamified learning app on different forms of learning outcomes with regard to taxonomy levels. Different hypotheses, which have been derived from traditional learning theory, are tested to contribute to the existing body of field studies. This study draws conclusions for the use of gamification in classic teaching environments and for the future development of learning concepts as well as research on learning effects.

2. Theoretical foundations

Gamification in General

Gamified learning utilizes game-like elements in non-game settings to shape students' behavior and attitudes, potentially leading to improved learning outcomes, both directly and indirectly (cf. Landers, 2015). Hence, gamification is a design process, intended to augment or alter an existing process. Thus, gamification is not itself a product. Instead, one adds game elements to change a process that already exists to change how that process influences people with the goal of creating a specific change in outcome (Landers et al., 2018). It is commonly assumed that by adding game attributes to non-game environments, motivation and engagement can be increased (Reeves & Read, 2009). In education and learning, gamification is primarily used to influence motivation and learning performance. This relationship, however, is not isolated but influenced by mediators which can include attitudinal, motivational, and behavioral effects (Landers et al., 2018; Schöbel et al., 2022).

From a game developer's viewpoint, game elements can be delineated using the Mechanics, Dynamics, and Aesthetics (MDA) framework. In this framework, mechanics represent the fundamental rules or elements of the game, dynamics encompass the interactions and behaviors of the player in relation to these mechanics, and aesthetics encapsulate the emotional responses elicited from the player (Hunicke et al., 2004). Robson et al. (2015) developed the MDA framework further to mechanics, dynamics and emotions (MDE). The focus of gamification lies primarily on mechanics. The goal therefore is not to design a game, but rather to harness the mechanics to encourage and reward behaviors that support learning and foster productive social interactions (Hung, 2017).

Adding game elements is an incremental and versatile process, ranging from the simple addition of one element to the addition of a complex set of elements (Armstrong et al., 2016). The specific list of game elements that can be applied and manipulated is also an issue of debate among gamification scholars. There are a few existing gamification-oriented game element taxonomies, most of which differ based on outcome of interest (Landers et al., 2018).

Reeves and Read (2009) list ten typical features of games: self-representation with avatars, narrative context, multi-dimensional environment, competition under clear rules, marketplaces, reputation and ranks, time pressure, teams, feedback, and communications. Bedwell et. al (2012) compile an even more comprehensive list of game attributes, which could be linked to learning: players or avatars, location, representation, interaction with the game, interaction with others, communication, stimuli, adaptation, assessment, progress, challenge, conflict, control, fantasy, mystery and surprise, rules, safety, and more. Similarly, Kiryakova et al. (2014) and Barata et al. (2015) identify the following game elements in case studies of typical learning platforms: users' avatars or profiles, visibility of progress, display of results, levels, feedback, badges, and leaderboards.

Gamification in Higher Education

Gamification is gaining attention in academia and practice, with an increasing use of game elements in teaching environments (Sailer & Homner, 2019; Caponetto et al., 2014; Kapp, 2012). Similar to its application in other domains, gamification in learning and teaching practice focuses on mechanics, thus the addition of game elements to an existing process. In an educational setting, gamification entails specific game elements, such as narrative and score tracking, employed in video games and applying these elements to enhance the learning experience (Landers et al., 2015).

Empirical studies on gamification in higher education have focused on game elements such as points, levels, badges and leaderboards (Dicheva et al., 2015), which are the most common game elements used in learning environments (Toda et al., 2018). In this regard, Koppitsch and Meyer (2022) concluded that implementing a point-based gamification system in quiz mode resulted in increased levels of reported student engagement compared to the traditional lecture format. Achievement-oriented affordances are the most commonly used compared to immersion-related affordances (such as avatars and narratives) (Koivisto & Hamari, 2019).

Effect of gamification in Higher Education

So far studies have shown little to no impact of gamification on academic performance (Barata et al., 2013). While some studies stipulate enhanced learning performance (Lo & Hew, 2020; Zainuddin et al., 2020), others such as Toda et al. (2018) show that a loss of performance was the most occurring effect of gamification and the leaderboard the most cited game design element with a negative effect.

A meta-analysis by Sailer and Homner (2019) suggests only small significant effects on cognitive, motivational, and behavioral learning outcomes from gamified learning, with cognitive effects being most stable. Cognitive outcomes are based on conceptual or application-oriented knowledge, whereas motivational outcomes include engagement or attitudes, and behavioral outcomes are based on specific skills or competences (Sailer & Homner, 2019). They thereby collect a range of moderating effects like the inclusion of game fiction, types of social interactions, various learning arrangements and more (Sailer & Homner, 2019; Klock et al., 2018).

One of the key challenges of these studies is that gamification often entails different game mechanics in combination, making the individual impact of an added game element hard to isolate. Courses can also be gamified to different extents ranging from adding an additional layer to making it an integrated part of every course (Hung, 2017). The use of game elements such as finite resources, levels, badges and points can create cooperation and or competition (Hung, 2017). And as Barata et al. (2014) suggest, gamification has a different effect on different types of students. Competition can be empathized further using leaderboards which allows students to compare themselves against others (de Byl, 2013), which might influence their patterns of use.

While the theory of gamified learning (Landers, 2015) proposes (positive) effects on behavior and learning outcomes, additional theories must be employed to deeper understand underlying psychological effects and mechanisms like self-determination theory (Seaborn & Fels, 2015; Zainuddin et al., 2020), flow theory (Csikszentmihalyi, 1975; Zainuddin et al., 2020) and appraisal theory (Scherer et al., 2001; Loureiro et al., 2020):

Gamification can primarily be seen to provide users with feedback (Koivisto & Hamari, 2019). Koivisto and Hamari (2019) distinguish three types of feedback: cognitive, affective and social feedback. The focus in gamification research often lies on affective or social feedback which aim for enjoyment, excitement or interest (Koivisto & Hamari, 2019), rather than an improvement of learning outcome or academic performance. Cognitive feedback provides information to the user based on game mechanics so that they can better monitor their progress (Hung, 2017). These so called "progression mechanics" are of particular importance (Robson et al., 2015) enabling students to track their progress and pinpoint areas where they can enhance their skills (Dehghanzadeh et al., 2021).

Game mechanics reward outcomes which are thus more likely to be repeated. Progress can be signaled using achievement rewards including scores, levels or progress bars among others (Robson et al., 2015). The visual depiction of progress and success motivates students to establish objectives, track their progress, and commemorate their achievements (Wulantari et al., 2023) and they also serve as a source of motivation, inspiring students to establish objectives and monitor their growth (Dehghanzadeh et al, 2021). However, the progress or achievement measurements are often superficial and do not correspond to actual learning (Hung, 2017). The goal should be that game mechanics (progress and achievements measurements) are not superficial but substantial, meaning they should assist students in understanding their performance in class (Hung, 2017).

Bacon (2016) pointed out the importance of distinguishing between actual and perceived learning. Following the educational assessment literature, Elbeck and Bacon (2015) distinguish between measurements of actual learning also called direct measures and perceived learning or passive measures. Actual learning is measured using tests or graded presentations perceived learning on the other hand is measured using student self-reports (Bacon & Stewart, 2022). Bacon (2016) mentioned that although the terms are used interchangeably, the correlation between actual and perceived learning has not been proven in research and that they are separate and distinct constructs.

This paper thus aims to contribute to the understanding of the impact of the use of a gamification element, a gamified learning app, as part of a comprehensive learning environment based on large-scale data of learning behavior and actual learning outcomes. As already mentioned above, it therefore focuses on actual learning rather than perceived learning behavior.

3. Study context

This study looks into the use and the effects of the use of a gamified learning app as part of an integrated learning environment. The study sample is the complete cohort of first year college students in a mandatory management course of a mid-sized European University. Around 65% of the first-year students are male, with an average age of 20 years across the cohort.

After one semester, the students must pass a term exam. The exam is held in the form of a paper-based test which is taken on campus. To prepare for the exam, the students spend around four to five weeks on intense, individual studying after the end of the teaching period. The term exam of the introductory course in management consists of two parts: A multiple-choice (MC) part emphasizing knowledge and understanding, and a case-study (CS) part focusing on actual application of knowledge and acquired skills.

The introductory course takes place over the duration of one semester. The semester is broken down in twelve weeks, interrupted by a two-week break in the middle of the semester. The introductory course in management is based on a dedicated textbook. The course is structured in weekly lectures, centered on one of the chapters. The lecture is supplemented by a weekly tutorial in groups of about 40 students. The tutorials discuss the material covered in the lecture based on a case study. The third pillar besides lectures and tutorials is self-studying. The material for self-studying such as the textbook, lecture slides and case studies from the tutorials are made available on the universities learning-management-system (LMS). In preparation for the final exam the students work through the material on their own.

In 2020, a new learning application was set up in collaboration with a third-party provider. The learning application has the goal to supplement the self-studying, is free of cost for the students and is available in the App-Store and on Android. The application is an additional learning tool which students can make use of on a voluntary basis. However, there is no formal control of the use by the students. The learning app can be accessed with the student's university login. On the application, students remain anonymous. The content of the application is structured along the twelve chapters of the textbook. The learning content is very close to the final exam. Students can choose one of the modules and are offered a set of twenty questions to answer.

The questions are in the form of multiple-choice questions and are based on the content covered in the textbook and therefore the content which is assessed in the final exam.

The application offered around 500 questions when the data for this study was collected. The number of questions is extended continuously.

The learning application uses different game elements such as points, leaderboard, and progress. The learning application is based on a spaced repetition algorithm and offers also a single- and a multiplayer mode.

Points and Leaderboard

For each correctly answered question, students are awarded a point. Students can then compare themselves to other students of the cohort on the leaderboard. No points are deducted if questions are answered incorrectly.

Progress

Progress is measured as follows. Students must answer the questions multiple times. If a question has been answered correctly three times in a row, they mastered the question. Once all questions available on the learning app have been answered correctly three times in a row, the students reach 100% progress.

In the case that a question has been answered wrongly, students will lose progress. Thus, the progress will serve as an indicator of the student's actual knowledge at any time, given that the students play regularly.

It is thus possible for students to climb the leaderboard by answering the same questions of one chapter correctly over and over, but not making any advancement on their progress. Compared to the progress measurement, the measurement of points is not affected by incorrect answers. Progress is thus a measurement of actual learning, while the points might act as a proxy for perceived learning.

Spaced Repetition Algorithm

A strong argument for the progress as a measurement of actual learning is the algorithm used to determine in which order the questions appear. The algorithm is based on the idea of spaced repetition. Out of the twenty questions in each set, at least five are new, until the student has answered all questions at least once. Questions that are answered correctly will move up a level until they are answered correctly three times in a row. If the question is answered incorrectly, the question will fall back to level one.

The time between the questions is 0 for new questions. For questions that are answered incorrectly it's 25 minutes (level one). For questions that are answered correctly once, the time is 7 hours (level two). For questions that are answered correctly twice, it's 1 day (level 2) and for questions answered correctly three times, it's 5 days (level 3). The underlying formula is:

$$25*(level)^{4.2}$$

Multiplayer Mode

Lastly, the application also offers a challenge mode. The students are assigned random students of the cohort. Both have to answer four questions on different chapters of the book within one round. The questions are identical for the two players. The player who answers the most questions correctly over the course of four rounds wins.

4. Hypotheses

Based on the existing body of knowledge as well as traditional learning theory, a set of hypotheses has been developed. Correlations between invested time, achievement, learning effort over time and learning outcomes are suggested. Furthermore, learning outcomes are investigated based on students' performance in both multiple choice (MC) and case study (CS) type exam questions.

Time spent: In line with the theory of gamified learning it can be expected that the intensity of use of the gamified learning app has effects on learning outcomes. Previous studies emphasize the role of invested study time (Stinebrickner & Stinebrickner, 2004). In the study at hand, learning outcomes can be measured based on points in the final exam. The more intensively gamification elements are used, the higher the point grades in the exam.

> ***H1:*** *The more time spent in the learning app, the more points achieved in the exam.*

Achievement: Intensity of use can not only be measured with time spent in the app, but also with the number of gamified questions or tasks handled. Unlike time spent, the number of achieved gaming points provides indications of the efficiency and seriousness of learning. This can also be related to self-determination theory, which underlines the importance of perceived competence (Ryan & Deci, 2000). It can be assumed that students who can experience their ability are more motivated to learn and, in the end, more successful in exams.

> ***H2-1:*** *The more points achieved in the learning app, the more points are achieved in the exam.*

> ***H2-2:*** *The more progress achieved in the learning app, the more points are achieved in the exam.*

Learning effort over time: Based on the course design with the build-up of knowledge and competencies throughout an entire semester, it can be assumed that more regular confrontation leads to deeper understanding. Theory suggests that deep immersion is necessary to perceive a flow (Csikszentmihalyi, 1975). It can be expected that students who regularly immerse themselves in the provided learning environment show better outcomes.

> ***H3:*** *The more evenly the in-app learning is distributed over time, the more points are achieved in the exam.*

Type of skills supported: Learning outcomes can be structured by using the theory of taxonomy levels (Bloom et al., 1956). It can be expected that students who are learning intensely in the gamified learning app are more successful in the rather similar multiple-choice (MC) part of the exam than in the part with open case study (CS) questions. While MC questions are mostly testing knowledge, CS exercises require actual application of concepts and frameworks.

> ***H4:*** *The correlation between the number of answered questions in the learning app and achieved points in the examination is higher in the multiple choice (MC) than the case study (CS) part.*

5. Empirical results

The empirical analysis draws on the comprehensive dataset of the students' interactions within the gamified learning app and their results in the (paper-based) term exam. The exam scores have been converted and linked to the individual students in a form that maintains data security and privacy. The analysis includes a total of 1598 students, the whole cohort of first term students in fall 2021.

H1: Students who spend more time in the learning app achieve higher grade points in management-related subjects.

The visual inspection of the distribution suggests a level-log transformation of the function (*points = a + b*ln[time] + e*). This makes sense as decreasing marginal returns can be expected in learning: It usually involves much more learning effort to move from a good grade to a very good grade than from a marginal to a satisfactory grade. The transformation results in the following model:

	R	**R^2**	**Adjusted R^2**	**Std. Error**	**Sig.**
Model	.407	0.165	0.165	21.7432	<.001

	B	**Std. Error**	**Beta (std.)**	**t**	**Sig.**
Constant	74.551	2.884		25.851	<.001
ln[time]	4.690	0.278	0.407	16.889	<.001

Table 1: Model and coefficient description of regression analysis of H1

Based on the model, H1 cannot be rejected: Results indicate that higher learning effort correlates with better results at the exam. The (level-log) model is strongly significant ($p < 0.001$). However, the impact of learning time on achieved exam points is somehow weak: +1% of time spent in the app corresponds to +0.05 points in the exam.

H2-1: Students who achieve more points in the app achieve more points in the exam.

Here again, the visual form of the distribution suggests a level-log transformation of the hypothesized function (*points = a + b*ln[questions] + e*), that provides the following model:

	R	R^2	Adjusted R^2	Std. Error	Sig.
Model	0.464	0.215	0.215	21.0831	<.001

	B	Std. Error	Beta (std.)	t	Sig.
Constant	74.775	2.454		30.465	<.001
ln[questions]	6.437	0.324	0.464	19.872	<.001

Table 2: Model and coefficient description of regression analysis of H2-1

A high number of answered questions does not necessarily mean that a student has been able to complete a higher number of questions correctly and repeatedly. Instead, it could also mean that the student did just repeat specific chapters very often – without covering the entire course. Therefore, the app provides another indicator: the so-called progress factor. It reflects the share of questions and topics of the entire management course that the student has covered by using the gamified learning app.

H2-2: Students with a higher progress score in the app achieve more points in the exam.

As most of the students achieved a progress score beyond 80%, the distribution is very left leaning. The modelled regression therefore needs to be considered with care ($points = a + b*progress + e$).

	R	R^2	Adjusted R^2	Std. Error	Sig.
Model	.427	0.182	0.182	19.8742	<.001

	B	Std. Error	Beta (std.)	t	Sig.
Constant	99.533	1.524		65.299	<.001
progress	33.100	1.932	0.427	17.128	<.001

Table 3: Model and coefficient description of regression analysis of H2-2

Based on these models, H2-1 and H2-2 cannot be rejected. These results indicate that higher learning progress correlates with better results in the exam. The models are strongly significant ($p < 0.001$). However, the effect sizes are relatively limited: +1% of answered questions corresponds to just +0.06 points in the exam (H2-1). Furthermore, +10 percentage points of progress in the app corresponds to only +3.3 (of 180) points in exam (H2-2).

H3: The better the in-app learning is distributed over time, the more points are achieved in the exam.

The third hypothesis builds on the assumption that students' deep immersion throughout the semester allows for a flow (Csikszentmihalyi, 1975). According to general learning theory as well as flow theory, students who engage more regularly in learning with the learning app will show better learning outcomes in management education. This hypothesis is tested with two approaches:

a) Cluster analysis: clustering students according learning patterns over time in form of their means of learning effort (time) per calendar week (CW 38 [semester start] until CW 04 [examination week]) and conducting a discriminatory analysis of the performance of these clusters.
b) Index calculation: calculating a mean deviation index (mean of the percentual deviation of weekly learning effort from the individual mean of weekly learning effort for the entire semester) and performing linear regression analysis ($a + b*index_{MD} + e$).

a) Cluster analysis

Based on a cluster analysis with 3 clusters, H3 cannot be rejected. Results indicate that even distribution of learning effort across time correlates with better results at the exam. Significant differences in total points achieved at exam between the cluster with more evenly distributed learning effort (cluster 2) and the other two clusters are found. Students from cluster 2 (more learning effort during lecture phase, small peak in exam preparation phase) have achieved significantly more points at the exam compared to all other students.

	F	**Welch**	**df 1**	**df 2**	Sig.
Model	14.224	18.671	2	715.036	.000

(A) Cluster	**(B) Cluster**	**Mean difference (A-B)**	**Std. error**	**Sig.**	
1	2	-7.2752	1.4270	0.000	***
	3	0.0182	1.7259	1.000	
2	1	7.2752	1.4270	0.000	***
	3	7.2934	1.8913	0.000	***
3	1	-0.0182	1.7259	1.000	
	2	-7.2934	1.8913	0.000	***

Table 4: Model and cluster description of cluster analysis of H3

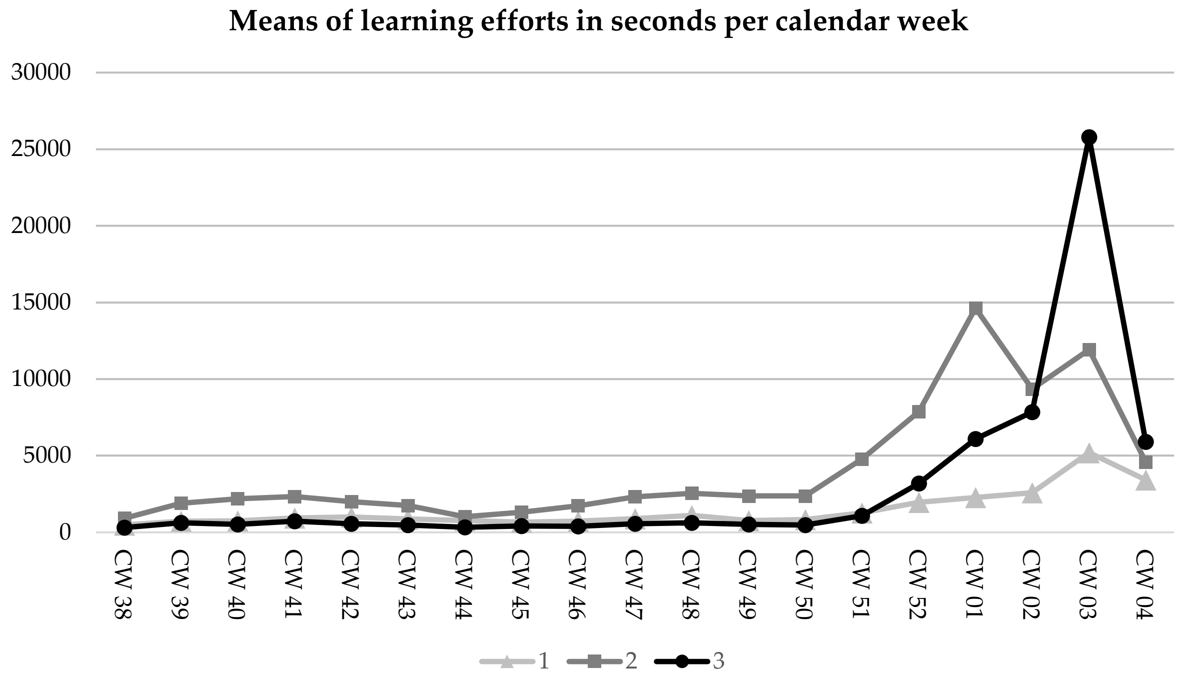

Figure 1: Resulting clusters of cluster analysis of H3

The model is strongly significant ($p < 0.001$). However, the effect sizes are relatively limited: On average, students from cluster 2 achieve about 7 points more at the exam compared to students from other clusters.

b) Index calculation

Based on the analysis with the mean deviation index, H4 cannot be rejected.

	R	**R^2**	**Adjusted R^2**	**Std. Error**	**Sig.**
Model	0.367	0.134	0.134	20.931	<.001

	B	**Std. Error**	**Beta (std.)**	**t**	**Sig.**
Constant	152.896	2.072		73.789	.000
Index MD	-22.880	1.552	-0.367	-14.742	<.001

Table 5: Model and coefficient description of regression analysis of H4 (mean deviation index)

Results indicate that even distribution of learning effort across time correlates with better results at the exam. The model is strongly significant ($p < 0.001$). However, the effect sizes are relatively limited: +1 in the index corresponds to -22.880 points in the exam (H4). Thus, the difference between a perfect equal distribution (index = 0) and 100% mean deviation of weekly learning effort from the individual mean of weekly learning effort for the entire semester (index = 1) is -22.804 points in the exam. Furthermore, -1% less mean deviation of weekly learning effort results in 0.228 points in the exam.

H4: Learning with the learning app improves the points in the multiple choice (MC) part more than in the case study (CS) part.

The fourth hypothesis builds on the assumption that gamified learning in the existing form with predefined questions delivering points and allowing for competitions is primarily strengthening skills on a taxonomically rather low level (know-what). The learning outcome in this sample was measured in an exam consisting of two parts: 50% points with single- and multiple-choice questions, which are somewhat similar to questions in the learning app, and 50% points with case study questions, which require actual application of knowledge (know-how) and are of a more qualitative, essayistic nature. The hypothesis is tested by comparing the learning effort to the exam results in the two distinct sections ($pointsMC = a + b*ln[questions] + e$ versus $pointsCS = a + b*ln[questions] + e$).

Effect on single/multiple choice part (MC):

	R	**R^2**	**Adjusted R^2**	**Std. Error**	**Sig.**
Model (MC)	0.444	0.197	0.196	9.485	<.001

MC-Part	**B**	**Std. Error**	**Beta (std.)**	**t**	**Sig.**
Constant	46.491	1.104		42.104	<.001
ln[questions]	2.738	0.146	0.444	18.792	<.001

Table 6: Model and coefficient description of regression analysis of H4 (part MC)

Effect on case study part (CS):

	R	R^2	Adjusted R^2	Std. Error	Sig.
Model (CS)	0.437	0.191	0.191	13.0541	<.001

CS-Part	B	Std. Error	Beta (std.)	t	Sig.
Constant	28.284	1.520		18.611	<.001
ln[questions]	3.698	0.201	0.437	18.441	<.001

Table 7: Model and coefficient description of regression analysis of H4 (part CS)

Interestingly, H4 must be rejected. The reproach of fostering low learning taxonomies only through gamified learning apps must thus be questioned. Results indicate that learning with the app (on average) correlates even (a bit) more with exam success in the case study (CS) than the multiple choice (MC) part. However, the scattering (error of the estimate) is bigger in the MC part, where it is generally more difficult to achieve higher points in the exam (cf. constants: MC 46 points, CS 28 points). Overall, +1% of answered questions corresponds to +0.03 points in the MC part, but +0.04 points in the CS part of the exam.

6. Discussion

The fact that hypotheses H1 and H2 cannot be rejected supports the idea of gamified learning as an instrument to improve learning (duration and intensity) and the resulting outcomes specifically in management education. The level-log-models are strongly significant ($p < 0.001$). However, the effect sizes are relatively small with a 1% increase of answered questions in the learning app corresponding to a 0.06-point (out of 180) increase of the points achieved in the management exam, and a 1% increase in the time spent in the app corresponding to a 0.05-point increase in the exam. The finding of significant correlations with small effects is in line with the results of the meta study from Sailer and Homner (2019). However, as no causal analysis was performed, this study can only confirm that higher learning efforts correlate with better results in the management exam. The low R-squared values (for time spent 0.165; for completed answers 0.215) show that there are important unobserved factors at play as only a small part of the variance can be explained with time spent (16.5%) or completed answers (21.5%). As time can be spent inefficiently (e.g., distractions from other apps), it is not surprising that "time" exhibits a smaller correlation with exam results than the number of completed questions in the gamified learning app.

The positive correlation between progress in the gamified learning app and the achieved grade points in the management exam is significant and, compared to the effects of pure time spent and answers given, relatively strong: plus 10 percentage points in progress corresponds to a plus of 3.3 points (out of 180) in the exam. Thus, if the two extreme cases of 0% and 100% progress within the app are compared, the expected difference at the exam is 33 points. This corresponds to a difference of more than a whole grade point (on a scale from 1 to 6). In line with the flow theory (Csikszentmihalyi, 1975), it could be argued, that students who perform well in the gamified app are motivated to invest more time and are therefore more successful in the exam. However, given that only correlations are investigated, the effect could also be different: The better and more self-disciplined students perform better in the app and the exam.

The analysis of the learning patterns over time (how learning is distributed over the semester) reveals that different types of students can be identified. The cluster analysis delivers valid and significant results for three clusters. The discriminator analysis also shows that a more regular learning pattern is correlated with better exam results, which corresponds to learning theory. The index analysis also strongly supports a correlation between learning patterns over time (even distribution of learning over the semester) and exam results. However, since causal analyses are not available, there is also the possibility that motivated, high-performing, and well-organized students are just more disciplined and therefore perform better at the exam. This assumption could be attributed to the fact that gamification in education leads to higher learning motivation among students, as they engage more intensively with the learning material (Orhan Göksün & Gürsoy, 2019), which ultimately leads to better knowledge and performance in exams (Dichev & Dicheva, 2017). Therefore, already more disciplined and high-performing students may benefit disproportionately from gamified learning environments, further enhancing their exam performance.

As mentioned, the gamified learning app is (in its current form) mainly promoting knowledge learning. Even though the app allows for a variety of question types, it can be seen as an efficient tool to (primarily) prepare for multiple-choice tests. Interestingly, the number of answered questions in the app corresponds similarly to the achievements in the very similar MC-part of the exam as in the more open CS-part of the exam (R-squared of 0.196 and 0.191). Moreover, the effect is even stronger (3.698, compared to 2.738) for the CS-part which requires the application of knowledge and skills. This result implies that learning in the gamified app is equally valuable for pure knowledge acquisition as for the actual application of knowledge. Again, there is the question of causality. It might also be that motivated, high-performing, and well-organized students learn intensively on the learning app and thus get better results in both parts of the exam because they exhibit higher levels of self-regulation and self-efficacy. And as the learning app is part of a wider ecosystem of learning tools like lectures, textbook and tutorials using cases the positive impact on higher taxonomy levels of learning outcomes might be driven by the combination of these different types of learning instrument.

Altogether, the presented results and this discussion indicate that the links between the use of gamified learning tools and learning outcomes are much more complex than observable here. There are many hidden variables at play (e.g., not just time spent, but seriousness of learning impacted by the context, for example, is the student learning in his study or at the bus station). Often, there might not just be direct causalities but also indirect and self-reinforcing effects (e.g., in line with the flow theory students who experience learning success are motivated to learn even more). Furthermore, attitudes to and experiences with specific (gamified) learning apps might also influence outcomes (cf. Landers & Armstrong, 2015). Complementing tools such as lectures and tutorials, textbooks, trial exams and other elements of the provided learning environment must be taken into consideration. Students with a high degree of self-regulation and organizational capabilities might for example not only be able to stick to a regular learning pattern in a gamified app but might also be able to make use of other course materials in a more structured way and thus achieve higher learning outcomes and exam results.

To control those variables and to provide data that allow for real causal analysis, more elaborate research designs like the use of control groups would be necessary. And here comes the tradeoff linked to much pedagogical research. Studies using data on actual learning show the real learning behavior and outcomes. But for ethical reasons deliberate control of variables or even the work with control groups are not feasible. On the other hand, more elaborate survey-based studies might allow the use of statistical analysis that reveal causal effects. But they just take into account perceived learning behavior.

7. Conclusion and limitations

The study provides what may be the largest database on actual learning in the context of management education for examining the impact of using a gamified learning tool. This study supports the positive impact of gamified learning on students' success in management courses. Consistent with existing studies, the effect is significant but relatively small.

In addition, the study sheds light on two important aspects of learning theory, namely the learning behavior over time and type of skills trained. In line with existing theory, the study supports the importance of regular learning over time. Interestingly, the study shows that gamified learning is not just promoting knowledge, but also correlating strongly with successful application of skills and frameworks.

As a conclusion, educators in management education might motivate students and develop mechanisms that encourage, enable, or even enforce regular learning patterns. The use of a gamified learning app with points and leaderboards, in combination with other learning instruments like tutorials or textbooks, also has a positive effect on higher levels of learning outcomes, such as the capability to apply knowledge in case studies, which are fundamental to management education.

However, the data and their discussion show that the effect of the learning app on student success might be more complex, as self-selection effects and several unexplained variables play a role. Self-selection, covariance effects, and other limiting factors might be at play.

Therefore, the study could also stimulate further research that moves from an analysis of individual effects of a tool on study outcomes to a more systemic analysis in the context of management education. Additional methods, such as learning diaries or focus groups for qualitative analysis, could provide additional insights into how gamified tools are perceived and utilized by management students.

However, there are limitations for ethical reasons. A simple method to approach a causality analysis would be to use control groups – which is not applicable in a real study setting for obvious reasons. Another limitation is that grades may gauge learning outcomes but fail to fully reflect skill and knowledge development due to various uncontrollable factors like personal issues and exam stress (Dias, 2017). It is therefore not possible to fully demonstrate the extent to which gamification has an impact on students' grades.

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