The Effects of Gamifying Mathematics Lessons at High School Level

Michael Kickmeier-Rust and Corsin Niggli
St.Gallen University of Teacher Education, St.Gallen, Switzerland

michael.kickmeier@phsg.ch
corsin.niggli@student.phsg.ch

Abstract: Gamification encompasses the utilization of "playful" or "game-like" elements within non-gaming contexts. It finds diverse applications, primarily within the realms of education/training and the workplace, with the aim of enhancing teamwork and productivity. Nonetheless, the concept of gamification remains a topic of significant debate. Several authors caution that gamification may undermine intrinsic motivation to learn or perform, particularly among younger audiences. Furthermore, the research community increasingly emphasizes potential negative consequences resulting from specific gamification mechanics, such as competition. In this article, we present an approach to gamification that combines competitive elements, albeit at the level of student groups rather than individuals. The idea is to minimize the exposure of underperforming individuals while capitalizing on collaborative group dynamics, wherein stronger students provide support to weaker ones. We conducted a quasi-experiment, comparing motivation and performance between a gamified classroom scenario and a conventional, non-gamified scenario. The results indicate that the proposed gamification approach boosts motivation and performance in contrast to the non-gamified condition. These findings contribute to a deeper comprehension of the effects of gamification and offer a realistic perspective on its beneficial impacts within educational settings

Keywords: Gamification, Mathematics, Motivation, Performance, Competition, Collaboration

1. Introduction

Gamification has become a ubiquitous element of our digital culture. One stumbles across elements of gamification in all domains, ranging from advertisements to work assignments. It is not surprising that the gamification of education has been in the interest of many researchers and developers. The fundamental idea is that learners at all levels of education, from primary school to workplace training would need some sort of extrinsic motivation to learn, respectively to learn better, for a longer period of time, with more focus, and so on. The fundamental solution to the challenge of providing extrinsic motivation is to enrich conventional learning settings or learning tools with certain elements of play and gaming. This solution, however, is subject of substantial debate. On the one hand, authors like Ian Bogust (2015) criticize gamification as marketing point and highlight that in many cases, it's not about the "game" but about the "-ification", indicating the poor and superficial integration of overly simple and meaningless game elements such as getting scores and badges for "primary features like interactions with behavioral complexity". Other authors warn about the potential detrimental effects of reward tasks and behaviors. Alfie Kohn (2018), for example, elaborates on negative impact of not providing additional rewards for certain tasks, once learners or users are accustomed to these rewards. On the other hand, the gaming and in particular the serious gaming community often considers gamification as a half-hearted, desultory attempt to make certain tasks fun. They criticize that gamification reduces the enormous potential, meaning, and the spirit of games to simple, repeatable elements in which "benefit, honor, and aesthetics are less important than facility" (Bogust, 2015). Initiatives that attempt to push and ensure the quality of serious games, for example the German quality certificate for serious games (ral-seriousgames.org), which is based on the DIN Serious Games elements meta data standard (DIN SPEC 91380:2018-06), deliberately excludes gamification as a certifiable application or product. In turn, the proponents of gamification certainly have a point. Learning, especially in formal learning settings such as schools, is not necessarily a fun and exciting task. In many domains, subjects, and topics learners don't have an intrinsic reason to learn or they at least believe not to have a reason. Oftentimes, learning is simple drill and practice, boring, and hard. The hypothesis that adding elements of motivation and fun, adding reasons to perform certain (learning) tasks, appears reasonable and justifiable.

In educational environments, the primary aim of gamification is to enhance learners' motivation, engagement, concentration, and potentially reduce frustration, ultimately leading to improved learning performance (Oliveira et al., 2023). Numerous studies have explored the impact of gamification applications in education. However, it is common for these studies to yield insignificant positive effects of gamification usage (e.g., Koivisto & Hamari, 2019). Furthermore, research on gamification often lacks clear and methodologically sound reporting of learning gains. Literature reviews by Oliveira et al. (2023), Nah et al. (2014), and Fadhli (2020) further support the notion that the effects of gamification remain unclear and vary across different studies. Nah et al. (2014) conclude that the investigation of gamification's impact is still in its early stages. In other words, we do not yet fully understand how different types of gamification work for different types of learners and in various situations. Oliveira et al.

(2023) suggest that personalization is a key factor for successful gamification implementation. However, a deeper understanding of gamification and its perception by learners is still needed, along with improved gamification design that positively influences learning performance (Rapp et al., 2019). Another critical aspect often inadequately addressed in gamification is the ethical challenges associated with its use. It is important to identify and characterize different gamification mechanics and types. Nadi-Ravandi and Batooli (2022), in a literature review, compile a list of commonly used gamification mechanics and elements. The most frequently reported mechanics and elements in the literature include points/scores, leaderboards/rankings, badges, progress indicators, graphical enhancements (e.g., avatars), unlocking new areas/levels/functions, rewards/prizes, and narrative elements. Essentially, there are different types of gamification: (i) mechanics that promote direct competition with others (e.g., leaderboards), (ii) a comparison with others or standards, and (iii) aesthetic enhancements. While type (iii) appears unproblematic, types (i) and (ii) are associated with the notion of comparing one's abilities to others. This can work well for high achievers but may have negative emotional and social effects on low performers, as they may constantly face reminders of their perceived inadequacy. Additionally, a significant group of learners may not be interested in any form of competition. Ethical concerns surrounding gamification are increasingly being addressed in research (e.g., Goethe & Palmquist, 2020; Kriz, Kikkawa, & Sugiura, 2022; Mazarakis, 2021). However, resolving these issues and achieving ethically unproblematic gamification implementation remains challenging.

In our current study, we present a conceptualized gamification scenario for the classroom. While gamification in typical e-learning applications has been widely investigated, gamifying a lecture within a regular classroom setting has received limited attention in the past. The target audience for the proposed scenario is 17 to 20-year-olds. Importantly, we have conceptualized a gamification scenario that harnesses the motivational power of competition while simultaneously mitigating potential adverse effects on low-performing individuals.

2. The Mathiade Gamification Scenario

Among the most commonly used mechanics in gamification are leaderboards, points, and badges (Oliveira et al., 2023; Yang et al., 2022). Thus, we have chosen to incorporate these mechanics into our gamification scenario. Additionally, we are utilizing a less explored and applied element of gamification, which is cooperation.

In educational settings, leaderboards represent rankings of learners based on measurable variables such as performance, achievements, diligence, and perseverance (Nebel et al., 2016). These leaderboards compare individuals' variables with those of their peers, creating a competitive environment. Competition is considered a fundamental element of games and play, aimed at motivating learners to persist in performing certain tasks. As pointed out by Landers et al. (2017), the presence of leaderboard leaders can provide others with a desirable goal to strive for, encouraging them to keep up with the leaders. This goal can enhance performance by directing attention, improving motivation and persistence, and promoting the use of goal-oriented strategies (Locke & Latham, 2002). Another less noticeable feature of leaderboards is that the comparison with others, such as classmates, provides criterial feedback. This feedback helps learners reflect on the connection between their individual effort and performance (Mekler et al., 2017). Yang et al. (2022) provide further detailed insights into how leaderboards affect learning. Schlömmer, Spiess, and Schlögl (2022) evaluated the effects of leaderboard positions on learners' immediate perception of stress, measured, for example, through heart rate variability. This allows us to incorporate this gamification element into our scenario.

The second gamification element in our scenario is cooperation. Cooperation can be viewed as a behavior facilitated by gamification (Riar, 2020; Riar et al., 2022), but it can also be considered a game mechanic in its own right (Erikson & Sammons-Lohse, 2021). Cooperation occurs when two or more individuals work together towards a common goal, where the actions of individuals positively influence goal attainment. Cooperation fosters the exchange of ideas, knowledge, and skills, while also influencing psychological variables and sentiments such as group norms and social identity. These factors, in turn, enhance motivation, engagement, and perseverance (Reza Keramati & Gillies, 2022). Extensive research has been conducted on the beneficial effects of cooperative learning (Johnson & Johnson, 2009).

Our gamification scenario, Mathiade, is designed for an entire mathematics lesson within a classroom setting. It combines competition and cooperation, both of which are expected to enhance performance. First, the teacher arranges students into groups of three or four, ensuring a balanced mix of stronger and weaker students as well as highly and less communicative students. The groups compete for points by solving mathematics tasks through an online interface (Fig. 1). Although each student works individually, they can see the live results (completed tasks and points) of other group members within the interface. With the aim of winning the competition, collaboration and mutual assistance among group members, especially the high performers and those with competitive characteristics, are encouraged. The mode of communication and collaboration among students is flexible. On a central screen in the classroom, students can view the live rankings of the groups (Fig. 2) without individual performance information. By providing a public ranking through the group leaderboard, we aim to reduce the exposure and potential stigmatization of low performers, thus alleviating stress and other detrimental social and emotional effects on individuals. The interface has been implemented using HTML 5 as a browser-based app. Dynamic functions, such as task display, scoring, live results display, and data storage, have been implemented with PHP and JavaScript. The backend relies on a mySQL database. The application includes an item pool, the student interface, the group leaderboard, and additional administrative functions.

Figure 1: Screenshots of the Mathiade app

3. Study Implementation

To explore the impacts of implementing gamification in a classroom lesson, we introduced Mathiade to the 10th grade students at a secondary school in Switzerland. Our aim was to assess whether the gamification scenario led to enhanced task performance and motivation, in comparison to a control group that did not experience gamification. It's important to note that the variable "performance" in this study does not solely refer to improvements in mathematical skills, but rather serves as an indicator of motivation, engagement, and particularly effort. Additionally, we examined potential gender differences and the contrasting outcomes between high and low performers. Moreover, we investigated whether the gamification scenario promoted collaborative group work and communication, specifically analyzing whether stronger students provided support to their weaker peers. For our study design, we opted for a quasi-experimental approach involving both a treatment group and a control group.

3.1 Participants

A total of 43 students took part in the research project. We recruited four classes from a 10th grade in a secondary school in Liechtenstein, with each class consisting of 10 to 12 students. The average age of the students was 17 years. To conduct the study, the class teacher organized heterogeneous groups of 2 to 4 students, taking into consideration their varying levels of performance and openness. Due to practical considerations, we allocated the students from each class to either the control group or the experimental group.

3.2 Procedure and Materials

All classroom activities were conducted by the regular class teacher, who received instructions on the procedures and maintaining systematic logs of collaborative events during the lessons. Initially, we conducted a baseline survey on student motivation. One week later, we implemented the mathematics competition scenario, with one group experiencing gamification and another group serving as the control group. After an additional week, we repeated the scenario while switching the control and experimental groups. During the mathematics competition, students were given a strict time limit of 30 minutes. Both groups were allowed to communicate and collaborate within their respective groups, although it was not explicitly required. Immediately after each session, we administered the motivation questionnaire again. Throughout the sessions, teachers recorded any relevant events, specifically focusing on collaborative activities.

The motivation questionnaire items were based on a specific questionnaire developed for the educational context of gamification (Sailer, 2016, 171-174). This questionnaire encompassed four dimensions of motivation related to gamification: social integration (Cronbach's $\alpha = 0.86$), experience of autonomy in terms of contributing to tasks ($\alpha = 0.76$), autonomy in decision-making ($\alpha = 0.81$), and a sense of capability ($\alpha = 0.72$). The questionnaire comprised a total of 13 items, utilizing a 7-point Likert scale for scoring.

For the mathematics competition, we created a set of 120 test items covering fraction arithmetic. The items included basic arithmetic operations such as addition, subtraction, multiplication, and division. Dividends and divisors were either integers or fractions. Examples of items include 5 + 3/8, 7/9 - 8, and 6/12 * 7/24. Students had to enter their answers in text fields as either integers or fractions (Fig. 2). In the control group, students completed the tasks using a traditional paper-pencil format. They were instructed to answer as many items as possible within the given 30-minute time limit.

4. Results

For motivation, we found higher values in the gamification (experimental) group (EG) as opposed to the control group (CG). The total motivation score was 4.64 (SD=1.42) in the EG and 4.15 (SD = 1.37) in the CG. Across the four sub-dimensions we found similar differences (Table 1). The clearest differences were found for the dimensions social integration (Dim 1) and ability to make decisions (Dim 3).

More informative is the individual change in motivation (posttest value immediately after the mathematics session – pretest value). As illustrated in Figure 2, the individual total motivation score increased slightly in the EG (M = 0.56, SD = 0.95) while in the CG there was almost no change (M = 0.06, SD = 0.94). The effect was the same for female and male students. Equivalent results were found in the four sub-dimensions of motivation. An ANOVA yielded a significant main effect of the condition EG vs CG (F(1) = 4.85008); p = .032) and no main effect for gender (F(1) = 0.00535); p = .942) and no interaction (F(1) = 0.73397); p = .395). The effect size h^2 of the condition EG vs CG was 0.076.

Table 1: Average Motivation in experimental (EG) and control groups (CG)

	Dim 1		Dim 2		Dim 3		Dim 4	
	M	SD	M	SD	M	SD	M	SD
EG	4.69	1.70	4.34	1.76	5.06	1.69	4.52	1.42
CG	3.69	1.69	4.23	1.65	4.47	1.74	4.19	1.45
Diff EG - CG	1.00		0.12		0.59		0.33	

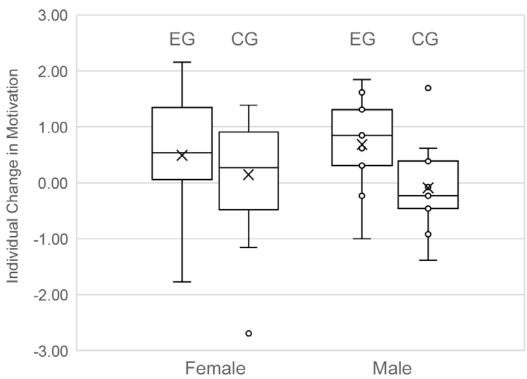

Figure 2: Individual change of motivation from pretest to gamified vs non-gamified sessions

In terms of performance, we found that the overall condition EG vs CG had an effect as well as the session date (gamification in the first session, no gamification in the second and vice versa). As shown in Figure 3a, the number of correctly solved tasks was clearly higher in the first session (T1: M = 32.58, SD = 19.89)) in comparison to the second session (T2: 48.87, SD = 29.56). Also, the condition (EG vs CG) had an effect; in the gamification condition the number of correctly solved tasks was lower (EG: M = 41.89, SD = 15.74) than in the paper-pencil condition (CG: 61.00, SD = 22.77). The sole consideration of the number of completed and correctly solved tasks is not a relevant factor for comparison between the conditions. The nature of the conditions renders such variables incomparable. The purpose of the gamification scenario is to facilitate communication and collaboration, which implies that the number of completed tasks may be lower. In terms of gamification, which fundamentally aims to enhance performance by motivating students, the key variable of interest is the loss of performance from one session to another. As depicted in Figure 3a, it is evident that in the gamification condition (EG), the decrease in performance (22%) is significantly lower than in the control group (CG) (69%). This difference is quite remarkable. A repeated measures ANOVA yielded a non-significant main effect for condition ($p = .157$), however, a significant main effect of time ($F(1) = 17.59$, $p = .001$) and a significant interaction ($F(1) = 13.64$, $p = .003$). A comparison of the performance in relation to gender revealed a clear difference (Figure 3b), while in the CG no performance differences occurred, in the gamification condition (EG) males performed better than females. A Kruskal-Wallis test yielded a significant effect of gender ($c^2 = 4.61$, $p = 0.032$, $e^2 = 0.153$) and no significant differences by the condition ($c^2 = 0.06$, $p = 0.804$, $e^2 = 0.002$).

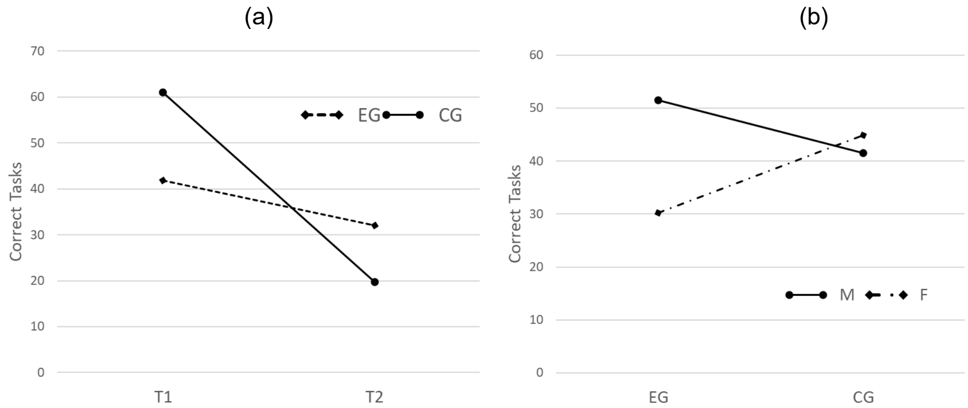

Figure 3: Performance (correctly solved tasks) in relation to session time (a) and gender (b)

The gamification scenario presented aims to promote collaboration within heterogeneous groups, with the expectation that stronger students would provide support to weaker students in order to maximize the overall performance of the group. Consequently, it was anticipated that stronger students would perform better in the absence of gamification (CG) and achieve lower performance in the gamification condition (EG). Conversely, it was expected that weaker students would benefit from the gamification condition (EG). When comparing the bottom and top 10% of students, we discovered indications supporting this effect. As illustrated in Figure 4, the stronger students (HP) performed clearly better in the CG ($M = 82.00$, $SD = 13.92$) than in the EG ($M = 53.20$, $SD = 10.60$). In turn, weaker students (LP) performed better in the EG ($M = 11.60$, $SD = 3.91$) than in the CG ($M = 7.40$, $SD = 3.03$).

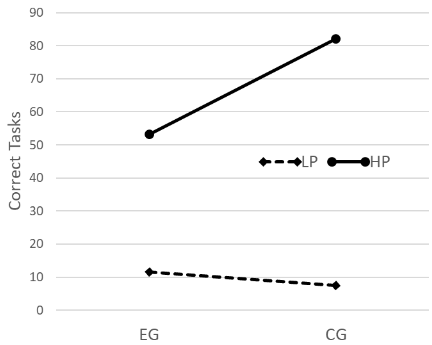

Figure 4: Performance (correctly solved tasks) in high (HP) and low performers (LP)

The analysis of the relationship between performance and motivation is summarized in Table 2. Overall, we found weak to moderate correlations between motivation and performance (defined as the number of correctly solved tasks). This holds for both, EG and CG. More interestingly, when considering the sequence of the respective session (EC – CG and CG – EG), we find stronger correlations in the second session, no matter if EG or CG. This is an indication that specifically in the second session the motivation plays a stronger role, presumably because motivation is substantially lower in the second session. In general, the dimensions ability to make decisions (Dim 3) as well as experience of capability (Dim 4) are stronger correlated with performance than the other two dimensions. The same effect was found for the individual change in motivation in relation to the pre-test scores (Table 2, Change). This remains difficult to interpret, it seems to be an indicator that the change – or an increase – in motivation is more relevant for the performance in a scenario without gamification support (CG).

Table 2: Correlation matrix of the dimensions of motivation and the total performance, time of the sessions (first EG followed by CG and vice versa), and the individual change in motivation

		Dim 1	Dim 2	Dim 3	Dim 4	Mot Tot
Total	EG	0.044	0.116	0.192	**0.382**	0.237
	CG	-0.229	-0.197	0.171	0.174	-0.013
EG - CG	EG	0.184	0.267	-0.169	**0.353**	0.235
	CG	-0.016	0.243	**0.423**	**0.469**	**0.323**
CG - EG	EG	0.135	0.276	**0.413**	**0.383**	**0.440**
	CG	0.074	-0.070	0.109	0.187	0.091
Change	EG	0.006	-0.063	0.082	0.054	0.051
	CG	-0.180	-0.299	**0.443**	**0.305**	0.218

5. Discussion

Research studies have revealed that collaborative educational environments, along with competitive educational environments, can contribute to the enhancement of various types of skills (Pareto et al., 2012). Furthermore, there is evidence suggesting that competitive reinforcement may have a more significant impact on the gaming experience of players compared to collaborative approaches involving positive and negative reinforcement (Sekhavat, 2020). Nevertheless, the effects of combining competition and collaboration, as well as how to effectively utilize the benefits of competitive reinforcement in collaborative-competitive serious games (CCSG), remain uncertain (Buchinger & da Silva Hounsell, 2018). For the relatively new genre of CCSG, it is crucial to systematically identify and compile design features for such games. The present study contributes to the comprehension of the effects of collaborative-competitive design features and mechanics.

In this paper, we presented a gamification scenario for an entire school lesson, emphasizing that competition is a strong motivating factor for students. However, we also discussed the potential downsides of gamification mechanics, particularly in relation to competition. For certain students, such as low performers and socially less integrated students, competition can have a negative emotional impact that may lead to a decline in performance. To mitigate these effects or at least reduce them, we proposed shifting the competition to heterogeneous groups consisting of both high and low performers as well as socially high and low integrated students. By doing so, we aimed to minimize individual students' exposure and promote communication and collaboration within the groups.

We implemented the gamification scenario in the context of a mathematics lesson and compared motivation and performance with a conventional, non-gamified scenario. Overall, we observed significant positive effects of gamification. Motivation in the gamification scenario (EG) increased compared to a baseline score, in contrast to the non-gamification scenario. This effect was observed for both female and male students, with the gamification condition (EG) showing higher motivation overall. The most notable difference in motivation was observed in the dimension of social integration (Dim 1), where average motivation in the gamification condition was one point higher on the 7-point Likert scale compared to the non-gamification condition (cf. Table 1).

When examining the performance difference between the gamification and non-gamification conditions, we did not specifically measure learning performance, but rather the extent to which students could demonstrate their competencies within the given session duration of 30 minutes. It is reasonable to assume that there was no increase in mathematics competencies for stronger students. However, weaker students may have benefited from the exchange with stronger students and potentially gained competencies. Identifying such effects will be a goal for future studies.

Task performance, as measured in this study, clearly demonstrated advantages for the gamification condition. It is important to highlight that the number of completed or correctly solved tasks alone is not a comprehensive performance indicator. It is expected that such figures would be higher in the non-gamification condition (CG), where all students can solely focus on completing mathematics tasks throughout the entire session. In contrast, in the gamification condition (EG), students dedicated time to communication and collaboration. The true desirable goal of gamification lies in (i) facilitating mutual benefits and social integration, (ii) increasing participation, and (iii) enabling students to showcase their full potential. Similar effects have been investigated in the context of sports education (Perlman, 2021; Ullrich-French, McDonough, & Smith, 2013), with studies demonstrating the benefits of group activities and even positive relationships with academic performance (Trudeau & Shephard, 2008).

In our study, we found that overall performance was lower in the gamification condition, but the performance decline in the second session was significantly lower with gamification. The gamification condition outperformed the non-gamification condition in the second session, indicating a remarkable and promising interaction effect (cf. Figure 3a). It is worth noting that females performed significantly less in the gamification condition, while no differences were found in the non-gamification conditions (Figure 3b). A possible explanation could be that females invest more time in supporting others and may have a stronger aversion to competitive elements compared to males. This finding aligns with the results of a large sample study conducted by Hartmann and Klimmt (2006).

One of the most positive effects observed was that the performance gap between stronger and weaker students was smaller in the gamification condition (Figure 4). This finding is further supported by the teacher's records during the gamification sessions. In summary, the teachers documented 31 communicative events in the gamification condition compared to 8 in the non-gamification sessions, as well as 27 collaborative events in the gamification condition compared to 8 in the non-gamification condition. Typical recorded events included instances where the strongest student assisted the weakest, continuous communication among students, and instances where a student who completed their tasks early helped others. Only in one group, which conducted the non-gamification session in the second time slot, did the students start communicating and comparing results.

Whether higher motivation and the associated increased effort exhibited by students justify the application of gamification remains a topic of ongoing debate. In conclusion, it is important to maintain realistic expectations regarding the potential benefits of gamification. Our study demonstrated that gamification can elicit various desirable effects in students. At the same time, it is crucial to raise awareness among developers and users about potential unintended and detrimental effects, such as embarrassing low performers. Future research must increasingly consider these effects and explore their long-term impacts.

References

Bogust, I. (2015). Why gamification is bullshit. In S.P. Walz and S. Deterding (Eds.), *The Gameful World: Approaches, Issues, Applications*. MIT Press.

Buchinger, D., & da Silva Hounsell, M. (2018). Guidelines for designing and using collaborative-competitive serious games. Computers & Education, 118, 133-149.

Erickson, L.V., & Sammons-Lohse, D. (2021). Learning through video games: The impacts of competition and cooperation. *E-Learning and Digital Media*, 18(1) 1–17.

Fadhli, M., Brick, B., Setyosari, P., Ulfa, S., & Kuswandi, D. (2020). A Meta-Analysis of Selected Studies on the Effectiveness of Gamification Method for Children. *International Journal of Instruction*, 13(1).

Goethe, O., & Palmquist, A. (2020). Broader Understanding of Gamification by Addressing Ethics and Diversity. In *HCI International 2020 – Late Breaking Papers: Cognition, Learning and Games. HCII 2020*. Lecture Notes in Computer Science, 12425. Springer, Cham.

Hartmann, T., & Klimmt, C. (2006). Gender and Computer Games: Exploring Females' Dislikes. *Journal of Computer-Mediated Communication*, 11(4), 910–931.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365–379.

Kohn, A. (2018). *Punished by Rewards. The Trouble with Gold Stars, Incentive Plans, A's, Praise, and Other Bribes*. Boston: Houghton Mifflin.

Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamifcation research. *International Journal of Information Management*, 45, 191–210.

Kriz, W.C., Kikkawa, T., & Sugiura, J. (2022). Manipulation Through Gamification and Gaming. In Kikkawa, T., Kriz, W.C., Sugiura, J. (Eds), Gaming as a Cultural Commons. *Translational Systems Sciences*, 28. Springer, Singapore.

Landers, R. N., Bauer, K. N., & Callan, R. C. (2017). Gamification of task performance with leaderboards: A goal setting experiment. *Computers in Human Behavior*, 71, 508–515.

Locke, E. A., & Latham, G. P. (2006). New theory directions in goal-setting. *Current Directions in Psychological Science*,15(5), 265–268.

Mazarakis, (2021). Gamification Reloaded: Current and Future Trends in Gamification Science. *i-com*, 20, 279-294.

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior*, 71, 525–534.

Nadi-Ravandi, S., & Batooli, Z. (2022). Gamification in education: A scientometric, content and co-occurrence analysis of systematic review and meta-analysis articles. *Educational Information Technology*, 27, 10207–10238.

Nah, F.FH., Zeng, Q., Telaprolu, V.R., Ayyappa, A.P., & Eschenbrenner, B. (2014). Gamification of Education: A Review of Literature. In: Nah, F.FH. (Eds.), *HCI in Business. HCIB 2014*. Lecture Notes in Computer Science, vol 8527. Springer, Cham.

Nebel, S., Beege, M., Schneider, S., & Rey, G. D. (2016). The higher the score, the higher the learning outcome? Heterogeneous impacts of leaderboards and choice within educational videogames. *Computers in Human Behavior*,65, 391–401.

Oliveira, W., Hamari, J., Shi, L., et al. (2023). Tailored gamification in education: A literature review and future agenda. *Education Information Technology*, 28, 373–406.

Pareto, L., Haake, M., Lindström, P., et al. (2012). A teachable-agent-based game affording collaboration and competition: evaluating math comprehension and motivation. Education Tech Research Dev, 60, 723–751.

Perlman, D.J. (2021). Examination of Self-Determination within the Sport Education Model. *Asia-Pacific Journal of Health, Sport and Physical Education*, 2(1), 79-92.

Rapp, A, Hopfgartner, F, Hamari, J, Linehan, C, & Cena, F. (2019). Strengthening gamification studies: Current trends and future opportunities of gamification research. *International Journal of Human-Computer Studies*, 127, 1-6.

Reza Keramati, M., & Gillies, R.M. (2022). Teaching cooperative learning through cooperative learning environment: a qualitative follow-up of an experimental study. *Interactive Learning Environments*, 1-13.

Riar, M. (2020). Using Gamification to Motivate Cooperation: A Review. International Conference on Information Systems (ICIS).

Riar, M., Morschheuser, B., Zarnekow, R., & Hamari, J. (2022). Gamification of cooperation: A framework, literature review and future research agenda. *International Journal of Information Management*, 67, 102549.

Sailer, M. (2016). *Die Wirkung von Gamification auf Motivation und Leistung.* Cham: Springer.

Schlömmer, M., Spieß, T., & Schlögl, S. (2021). Leaderboard Positions and Stress—Experimental Investigations into an Element of Gamification. *Sustainability*, 13(12), 6608.

Sekhavat, Y. A. (2020). Collaboration or battle between minds? An attention training game through collaborative and competitive reinforcement. Entertainment Computing, 34, 100360.

Trudeau, F., & Shephard, R.J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity*, 5(10).

Ullrich-French, S., McDonough, M.H., & Smith, A.L. (2013). Social Connection and Psychological Outcomes in a Physical Activity-Based Youth Development Setting. *Research Quarterly for Exercise and Sport,* 83(3), 431-441.

Yang, C., Shao-Ying, G., Zhen, Yang, C., & Yan-Qing, W. (2022). More challenging or more achievable? The impacts of difficulty and dominant goal orientation in leaderboards within educational gamification. *Journal of Computer Assisted Learning*, 38(3), 845-860.