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Understanding students' perceived need satisfaction, enjoyment, and participation intention in a leaderboard-based math practice game

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Fei Gao
Department of Applied Technology, Bowling Green State University, Bowling Green, OH, USA

Kimberly Cervello Rogers
Department of Mathematics and Statistics, Bowling Green State University, Bowling Green, OH, USA

Lan Li
College of Education & Human Development, Bowling Green State University, Bowling Green, OH, USA

Abstract

Though many studies suggest the positive effects of leaderboard on participants' learning and motivation, research also shows that not all students benefit from the use of leaderboard. Based on self-determination theory (SDT), this study examined how students' actual competence, perceived competence, perceived autonomy, and perceived relatedness affected students' enjoyment and intention for future participation in a leaderboard-based math practice game. The results showed that both perceived competence and perceived autonomy were closely related to students' enjoyment and intention for future participation, while students' actual competence and perceived relatedness were not related to their enjoyment or intention for future participation in such leaderboard-based math practice games. The findings of the study offer valuable insights and recommendations for both gamification research and practice.

Keywords

Gamification, leaderboard, math education, self-determination theory, motivation

Corresponding author:
Fei Gao, Department of Applied Technology, Bowling Green State University, 260 Technology Building, Bowling Green 43403, OH, USA.
Email: gaof@bgsu.edu

Introduction

Gamification is defined as "using game design elements in non-game environments" (Deterding et al., 2011: 2). In the past ten years, gamification has been applied in a variety of contexts such as retail, media, consumer goods, healthcare, and education to improve human motivation and performance (De Sousa Borges et al., 2014; Dehghanzadeh et al., 2023; Wünderlich et al., 2020). Researchers have conducted studies examining the effectiveness of gamification in promoting motivation and learning in disciplines such as reading, math, science, nursing, and management, and the findings suggested that gamification has potential to improve both performance and motivation (Kalogiannakis et al., 2021; Lämsä et al., 2018; Malicki et al., 2020; Papadakis et al., 2023; Watson-Huggins and Trotman, 2019). One of the most commonly used game elements in gamification design is the leaderboard, which displays participants' current scores and rankings. Although there is evidence indicating that leaderboards are among the most effective gamification features for enhancing motivation and participation (Saleem et al., 2022; Xu et al., 2021), some researchers have noted that these comparative scoring systems can demotivate those at the bottom of the leaderboard (Nicholson, 2015). Given the controversial nature of this gamification feature, it is evident that further research is required to gain deeper insights. To address this need, drawing upon self-determination theory (SDT) (Ryan and Deci, 2017), we explored the connection between students' perceived need satisfaction and their levels of enjoyment and intention for future participation in a leaderboard-based math practice game.

Literature review

Research on leaderboards

Research on leaderboards has examined (a) how the integration of leaderboards impacted participants' learning and motivation (Landers et al., 2017; Landers and Landers, 2014; Mekler et al., 2017; Ortiz-Rojas et al., 2019; Sailer and Sailer, 2021); (b) how different leaderboard design impacted participants' motivation and learning differently (Bai et al., 2021; Chernbumroong et al., 2017); and (c) how individual characteristics affected participants' experience of using leaderboards (Jia et al., 2017). While most studies report positive outcomes from using leaderboards (Kalogiannakis et al., 2021), its negative effects on participants' attitudes and motivation have also been documented in the literature (Andrade et al., 2016; Nicholson, 2013; Ninaus et al., 2020). It is evident that not all participants benefit from being engaged with leaderboards (Chernbumroong et al., 2017; Mekler et al., 2017). Na and Han (2023) suggested that "these ambivalent empirical results require answers as to 'why' and 'how' leaderboards fail" (p. 2). Yet, research examining the reasons behind these inconsistent effects remains limited. In this paper, we attempted to identify underlying psychological factors influencing students' enjoyment and their intention for future participation in a leaderboard-based learning activity. By exploring these factors, we hope to shed light on the sometimes contradictory outcomes observed in leaderboard-based gamification research. Self-determination theory (SDT) was utilized as our theoretical framework to explore these dynamics.

Self-determination theory and gamification research

As one of the most influential models on human motivation, SDT assumes that "healthy individuals are proactively interested in their surroundings and experiences, naturally engaged and assimilative

in an ongoing way" (Ryan et al., 2021: p. 98). According to SDT, people are motivated to grow and change by three innate and universal psychological needs: autonomy, competence, and relatedness (Deci and Ryan, 2004). The satisfaction or negligence of these three psychological needs in social environments can either facilitate or forestall autonomous types of motivation, which are conducive to engagement and optimal learning in educational contexts. The three psychological needs are (a) autonomy: "being the perceived origin or source of one's own behavior" (Deci and Ryan, 2004, p. 8), (b) competence: "feeling effective in one's ongoing interactions with the social environment and experiencing opportunities to exercise and express one's capacities" (Deci and Ryan, 2004: p. 7), and (c) relatedness: feeling loved or cared for.

As one of the most widely cited theories in gamification research (Krath et al., 2021), SDT has been applied in gamification research in various ways. Researchers have adopted SDT to study if specific gamification features satisfy the three basic psychological needs. For example, Sailer et al. (2017) examined a list of game elements and concluded that badges, leaderboards, and performance graphs positively affected competence need satisfaction, while avatars, meaningful stories, and teammates positively affected relatedness need satisfaction. Xi and Hamari (2019) found that immersion-related gamification features were positively related to autonomy need satisfaction and achievement-related features were positively related to all three types of perceived need satisfaction. Additionally, SDT has been adopted to investigate whether certain gamification features lead to increased intrinsic motivation, often measured by the Intrinsic Motivation Inventory (IMI) (Ryan et al., 1983), a SDT-based instrument. Sailer and Sailer (2021) reported that a gamified quiz with points and a team leaderboard positively affected intrinsic motivation and psychological need satisfaction in a gamified flipped classroom. Conversely, Mekler et al. (2017) found that in their study, game elements such as points, levels and leaderboards did not significantly affect competence need satisfaction or intrinsic motivation. Lastly, SDT has been used to guide the design of gamification activities or programs to support learners' perceived need satisfaction, motivation, or performance. Zhao et al. (2021) studied a gamified interactive e-book designed based on SDT and found a positive impact on students' performance, motivation and metacognition tendency. Van Roy and Zaman (2019), however, reported that, although a gamified online learning community was designed to support student basic psychological needs based on SDT, students only felt partially supported in their needs, and their need for competence or autonomy was sometimes thwarted due to situational factors.

Current research on gamification based on SDT presents several limitations. First, although there has been some exploration into how the satisfaction of basic psychological needs correlates with intrinsic motivation indicators like enjoyment and continued intention for future participation (e.g., Wang et al., 2021), such studies are limited. There remains a need to clarify the gamification mechanisms by delineating the relationships between the the basic psychological need satisfaction and intrinsic motivation (Jahn et al., 2021). Moreover, existing studies predominantly investigate the perceived need satisfaction of participants in gamified systems that incorporate multiple game elements (Baah et al., 2023; Javier Sotos-Martinez et al., 2024), making it challenging to isolate the effects of individual game elements on participants' perceived need satisfaction (Landers, 2014). Understanding the mechanism of how a specific game element functions is crucial for creating effective gamified interventions that untilize multiple game elements. Finally, while some researchers suggested that low-performing students were more likely to be demotivated by the competitive nature of such game elements as leaderboards (e.g., Andrade et al., 2016; Nicholson, 2015), there have been few studies investigating the direct relationship between individuals' actual competence and their motivation in terms of enjoyment and intention for future participation. To address these gaps in the literature, this study aimed to examine whether and how students' level of

enjoyment and intention for future participation are related to their perceived autonomy, competence, relatedness, and their actual competence in a leaderboard-based math practice game. Specifically, we considered the following research questions:

1. What levels of perceived need satisfaction, enjoyment, and intention for future participation did students report when participating in the leaderboard-based math practice game?
2. How were the dimensions of students' perceived need satisfaction (i.e., perceived autonomy, perceived competence, and perceived relatedness) associated with their enjoyment and their intention for future participation?
3. How did students' actual competence relate to their enjoyment and intention for future participation?

Method

Participants

Participants were 47 undergraduate students enrolled in a foundational math class titled *Real World Math Skills* at a public midwestern university. This course served to satisfy the state-mandated *quantitative reasoning* requirement for undergraduate students pursuing majors in art, music, and other non-STEM fields. Of all the participants, 44.68% was male and 55.32% was female. The average age of the participants was 20.28 with a standard deviation of 3.13.

Instrument

A survey consisting of 19 seven-scale Likert questions was developed to measure (a) the levels of students' perceived need satisfaction in autonomy, competence, and relatedness; (b) students' enjoyment in participating in this leaderboard-based math practice; and (c) students' intention for continuing to use leaderboard-based math practice games in the future. More specifically, three subscales in the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) (Chen et al., 2015) were adopted to measure students' satisfaction of competence, autonomy and relatedness with four questions under each subscale. Some example questions are "I felt competent when answering the questions" (Competence), "I felt like the gamified practice reflected how I want practices to be myself" (Autonomy), and "I felt connected to other participants" (Relatedness). Then, four items from the subscale of Interest/Enjoyment in Intrinsic Motivation Inventory (Ryan, 1982) was used to measure students' enjoyment. An example question is "I enjoyed doing this activity very much." Finally, three more questions were included in the survey to measure students' intention for continued use of leaderboard-based math practice games in the future, such as "I intend to participate in such math practice games in future classes."

Procedures

Prior to the class, the instructor created a set of 24 math problems designed to review content broadly centered around *Contending with Change*. Specifically, the 24 problems addressed topics related to (a) creating and using tables, graphs, and equations to model real-world situations; (b) creating basic linear and exponential models for real-world problems; (c) being able to choose whether a linear or exponential model is most appropriate for a given context and describe the limitations of the proposed models; and (d) solving real-world problems relating to rates of change. These

24 problems were entered into Quizalize (https://www.quizalize.com/), an online site for creating gamified quizzes. The difficulty level of the problems was intentionally set to moderate to ensure that students' scores would span across a wide range rather than clustering within a narrow range. This distribution would enable us to explore how students with varying levels of math competence responded differently to the gamified math practice. During an in-person class session, students utilized pseudonyms to log onto the site using their own mobile devices and worked on the Quizalize problems. Upon completion of each problem, students received immediate feedback and points on their mobile devices based on their accuracy, proceeding to the next question thereafter. Simultaneously, a leaderboard was projected onto a large screen at front of the classroom, displaying real-time student rankings. Once all students completed the 24 problems, their final ranking on the leaderboard presented their performance in the practice relative to their peers. Subsequently, students completed the survey outlined in the Instrument section.

Data collection and analysis

Data collection. Student performance data were obtained from the Quizalize site, including the total number of questions answered correctly and the percentage of accuracy. The count of correctly answered questions was used as a measure of students' actual competence in the subsequent analysis. Students' responses to the Likert questions were coded into numbers ranging from 1 (strongly disagree) to 7 (strongly agree). Students' scores on each of the six sub-categories including perceived competence, perceived autonomy, perceived relatedness, enjoyment, and intention for future participation were calculated using the mean of their ratings on the survey items in each sub-category.

Data analysis. To address research question 1, initial analyses were conducted to examine the variations of students' scores on the six measures: actual competence, perceived competence, perceived autonomy, perceived relatedness, enjoyment, and intention for future participation. To further examine the levels of students' perceived need satisfaction, enjoyment, and intention for future participation, one sample t-tests were conducted. Since number 1 in the survey represents "strongly disagree", and 7 "strongly agree", we use number 4, that is (7 + 1)/2, to represent a relatively neutral attitude. Using one sample t-tests, students' scores on the six sub-categories were compared with 4 to determine the levels of students' perceived need satisfaction, enjoyment, and intention for future participation. To address research question 2 and 3, correlations among all the variables were calculated. Based on the results, linear regressions were conducted to understand how these variables predict students' enjoyment and intention for future participation, both individually and collectively.

Results

Levels of perceived need satisfaction, actual competence, enjoyment, and intention

Table 1 and Figure 1 reveal significant variations in student scores, indicating a wide range of experiences among students participating in this leaderboard-based math practice game.

In addition, the results from the t-tests shows that students had a moderately positive attitude toward competence need satisfaction [t (46) = 3.06, p = .004], enjoyment [t (46) = 2.31, p = .025], and intention for future participation [t (46) = 2.02, p = .049], but a negative attitude toward

relatedness need satisfaction [t (46) = −3.74, p = .001]. Students had a relatively neutral attitude toward autonomy need satisfaction, as shown in Table 2.

Relationships between perceived need satisfaction, actual competence, enjoyment, and intention

Table 3 presents the correlations among all variables. Students' actual competence was not correlated with either enjoyment or intention for future participation. In contrast, students' perceived competence is significantly correlated with both enjoyment and intention for future participation. Strong correlations ($r >= \pm 0.70$) (Creswell and Guetterman, 2019) were observed between perceived autonomy and enjoyment, as well as between perceived autonomy and intention for future participation.

Furthermore, the results of linear regressions in Table 4 showed that perceived competence and perceived autonomy significantly predict students' enjoyment and intention for future participation individually. When both were added to predict enjoyment and intention, only perceived autonomy emerged as the significant predictor.

Discussion

This study examined the effects of a leaderboard-based math practice game on students' perceived need satisfaction, enjoyment, and their intention for future participation in such activities. The study also explored how students' perceived need satisfaction and their actual competence were related to their enjoyment and their intention for future participation. The main findings are summarized and discussed below.

To answer research question 1, the findings indicated significant variability in students' satisfaction of basic psychological needs within the leaderboard-based math practice game. Some students experienced low levels of need satisfaction, while others experienced high levels. Similarly, enjoyment and intention for future participation varied greatly among students, with some showing strong enjoyment and intent to participate in the future, while others exhibited limited enjoyment and little intention to participate. Furthermore, t test results revealed an overall positive effect of the leaderboard-based math practice game on students' competence need satisfaction, enjoyment, and intention for future participation. This finding aligns with prior research demonstrating that leaderboards may positively influence perceived need satisfaction (Sailer et al., 2017; Xi and Hamari, 2019). However, the study also revealed a negative effect on students' relatedness need satisfaction, likely due to the independent nature and the competitive

Table 1. Descriptive statistics of students' scores.

	Actual competence	Perceived competence	Perceived autonomy	Perceived relatedness	Enjoyment	Intention
M(SD)	13.68 (4.18)	4.73 (1.64)	4.33 (1.73)	3.20 (1.46)	4.56 (1.67)	4.52 (1.78)
Minimum	6	1.00	1.00	1.00	1.00	1.00
Maximum	23	7.00	7.00	6.00	7.00	7.00
Range	17	6.00	6.00	5.00	6.00	6.00
Skewness	.242	−.384	−.069	.040	−.109	−.130

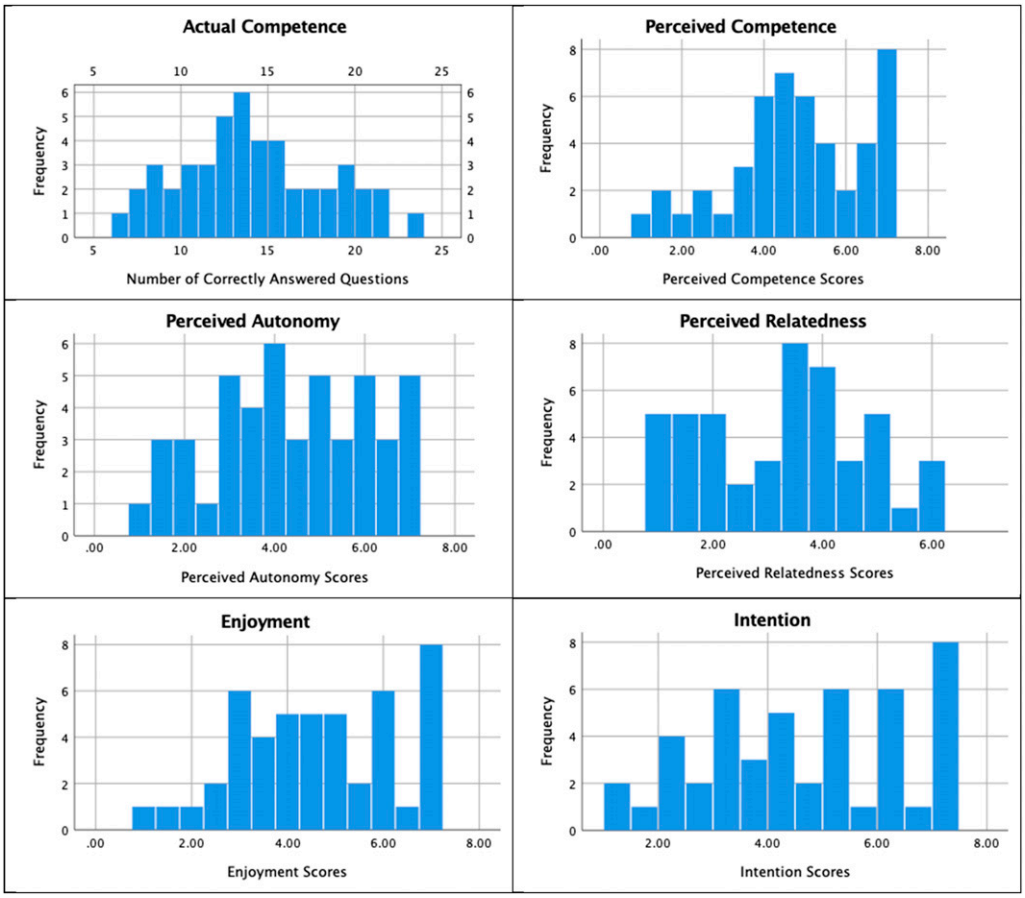

Figure 1. Histograms of students' scores.

Table 2. t-Tests results of students' perceived need satisfaction, enjoyment and intention. (n = 47).

Variable	Mean	SD	t	p
Perceived competence	4.73	1.64	3.06	.004**
Perceived autonomy	4.33	1.73	1.31	.198
Perceived relatedness	3.20	1.46	−3.74	.001**
Enjoyment	4.56	1.67	2.31	.025*
Intention	4.52	1.78	2.02	.049*

**Significant at the 0.01 level.
*Significant at the 0.05 level.

aspect of the activity. While individual leaderboard may not foster a sense of relatedness, Sailer and Sailer's (2021) study suggested that teamed leaderboard might enhance social relatedness without significantly affecting competence need satisfaction. Additional research is necessary to validate these findings.

Table 3. Means, standard deviations, and correlations. (n = 47).

	M	SD	1	2	3	4	5
1. Actual Competence	13.68	4.18	-				
2. Perceived competence	4.72	1.64	.624**	-			
3. Perceived autonomy	4.33	1.73	.135	.549**	-		
4. Perceived relatedness	3.20	1.46	−.235	.154	.321*	-	
5. Enjoyment	4.56	1.67	.167	.321*	.703**	.223	-
6. Intention	4.52	1.78	.200	.355*	.772**	−.008	.793**

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 4. The relations between perceived competence/autonomy and enjoyment/intention for future participation. (n = 47).

Dependent variable		Independent variable	b	t	p
Enjoyment	Step 1	Perceived competence	.328*	2.275	.028
	Step 2	Perceived autonomy	.680**	6.639	.000
	Step 3	Perceived competence	−.095	−.729	.470
		Perceived autonomy	.729**	5.921	.000
Intention	Step 1	Perceived competence	.386*	2.545	.014
	Step 2	Perceived autonomy	.793**	8.138	.000
	Step 3	Perceived competence	−.107	−.865	.392
		Perceived autonomy	.849**	7.259	.000

**Significant at the 0.01 level.
*Significant at the 0.05 level.

To answer research questions 2 and 3, the results indicated that variations in students' enjoyment and intention for future participation were not related to their actual competence but are associated with their perceived competence and perceived autonomy. This finding challenges the common assumption that students who perform poorly or have lower competence levels may be discouraged or demotivated by leaderboards (Andrade et al., 2016; Nicholson, 2013; Ninaus et al., 2020). Instead, it aligns with Bai et al.'s (2021) discovery that students' leaderboard ranking, an indicator of their actual performance, does not affect their course engagement. This finding is significant as it suggests that students with lower performance may still derive enjoyment from leaderboard-based activities if they perceive themselves as competent and autonomous.

The study has significant implications for future research. First, by deliberately isolating the examination to a single game element, namely the leaderboard, this study aligns with prior calls in the literature emphasizing the importance of dissecting individual game components to understand their unique impacts (Landers et al., 2019). This focused approach allows for a deeper comprehension of how leaderboards operate within educational environments, particularly as their motivational effects may fluctuate across different contexts (Rapp et al., 2019). Moving forward, future research is needed to explore the motivational influences of leaderboards across diverse learning settings. For instance, researchers could investigate how leaderboards function within collaborative learning environments versus competitive ones. Additionally, studies might be conducted to explore the effectiveness of leaderboards in promoting students' intrinsic motivation across a spectrum of

academic disciplines. By delving into these nuanced contexts, future research can offer insights into harnessing leaderboard-based gamification to optimize student engagement and learning outcomes across various educational contexts. Second, beyond identifying the overall effects of gamification, the study showed the diverse experiences and responses of students. Comprehending these variations is crucial for researchers to interpret the inconsistent findings in current leaderboard research and will stimulate further investigation into factors contributing to such diversities. Inspired by the results of this study, we conducted a follow-up study examining whether and how the big five personality traits (Goldberg, 1992) influence students' perceived need satisfaction, enjoyment, and intention for future participation in leaderboard-based learning activities. By probing into individual differences in personality traits and their connection with perceived need satisfaction, we aim to shed further light on the intricate interplay between psychological factors and gamification mechanisms. Third, our results suggested that perceived autonomy and perceived competence account for the variations in students' enjoyment and intention for future participation, which is consistent with the principles of self-determination theory (Ryan and Deci, 2017). Further research with a larger sample size is needed to not only validate the observed relationships but also facilitate a more nuanced understanding of how individual differences influence the effectiveness of leaderboard-based activities. Since learners with gamification features not tailored to their own needs tend to have a high level of amotivation (Lavoué et al., 2019), this increased understanding will enhance the overall engagement and motivation levels of learners as well as contribute to the refinement of individualized educational practices.

The study also has significant practical implications for leaderboard-based gamification in education. First, it is important for educators to recognize that, while leaderboards can yield positive outcomes overall, they may not work universally for everyone. This highlights the necessity for educators to diversify their gamification approach to accommodate varying student preferences and motivations. Second, the research suggests that implementing individual leaderboard-based activities may not always foster social connection among students. It's crucial for educators to consider the potential for such activities to inadvertently alienate certain students, leading to feelings of isolation or disconnection within the classroom environment. Third, the findings emphasize the potential effectiveness of appropriately designed leaderboard-based learning activities, even for students with lower levels of competence. This implies that students with varying skill levels can derive enjoyment and engagement from such activities, particularly if they perceive a sense of competence and autonomy during the learning process. As a result, educators can leverage leaderboard-based gamification strategies to motivate and engage a diverse range of learners.

The study has a few limitations. First, the sample size of the study is relatively low. Due to the limited sample size, the conclusions are tentative. Research with a significantly larger sample size is needed to corroborate the current findings. Such a larger-scale investigation will provide a more robust foundation to support the conclusions drawn from this study and inform future research directions. Second, the study's design poses challenges in determining whether students' positive attitudes toward perceived competence, enjoyment, and intention stemmed from their engagement with the leaderboard or solely from completing the math task itself. To address this ambiguity, future experimental studies could compare leaderboard-based practice with non-gamified practice. By conducting such comparative analyses, researchers can disentangle the effects of leaderboard engagement from the inherent effects of math practice, providing clearer insights into the motivational impacts of leaderboard. Finally, it's worth noting that, in the present study, students engaged in the leaderboard-based math practice game only once. This limited exposure raises questions about the potential long-term effects of leaderboards, particularly on students with lower competence levels. Nicholson (2013) noted that some students with lower competence levels

gradually gave up trying hard in a leaderboard-based learning system because their ranking stabilized after a few weeks, leaving them feeling that they had little chance of advancing. As a result, future research should investigate whether long-term leaderboard-based learning programs might lead to any negative impacts on these students' motivation and engagement. Previous studies have suggested that relative leaderboards, which emphasize students' position changes relative to a select group with similar rankings, could mitigate negative impacts and promote a more supportive learning environment (Bai et al., 2021; Chernbumroong et al., 2017). Therefore, exploring the effects of different leaderboard formats over extended periods could offer valuable insights into designing more effective leaderboards in educational contexts.

Conclusion

This study explored the relationships between students' perceived need satisfaction, actual competence, enjoyment, and intention for future participation in a leaderboard-based math practice game. The findings unveiled significant variations in students' experiences and attitudes towards the gamified activity and demonstrated the positive effects of students' competence and autonomy need satisfaction on their enjoyment and intention for future participation. The study's implications extend beyond the realm of research, offering practical insights for educators integrating leaderboard-based gamification in education. It suggests the need for educators to acknowledge the diverse responses to gamified activities and to tailor their approaches to accommodate individual student preferences and motivations. In sum, this study contributes to a deeper understanding of the complexities inherent in leaderboard-based gamification and highlights the importance of considering individual differences and psychological factors in designing effective gamified learning experiences. Further research is warranted to explore the nuanced dynamics of leaderboard-based gamification across diverse learning contexts and student populations, thereby enhancing educational practices and promoting student engagement and motivation.

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ORCID iD

Fei Gao https://orcid.org/0000-0003-3351-457X

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Author Biographies

Dr Fei Gao is a professor of instructional design and technology at Bowling Green State University. Her research is focused on how to cultivate reflective and motivated learners by supporting their autonomy and competence in computer-assisted learning systems. She has designed online learning environments, such as gamification-based learning environments and 3D virtual reality simulation to improve learners' cognitive, affective, metacognitive, and motivational dimensions of learning.

Dr Kimberly Cervello Rogers is a professor of mathematics education at Bowling Green State University. As foundational mathematics coordinator, she endeavours to enhance the teaching- and learning-efforts in undergraduate mathematics courses by helping graduate students and faculty members enhance their pedagogical knowledge and repertoire. Her research focuses on investigating knowledge mathematics teachers need for teaching and how professional development might impact their knowledge and classroom instruction, especially at the collegiate levels.

Lan Li is a professor of classroom technology at Bowling Green State University and holds a Ph.D. in Educational Studies. Her research interests include technology-facilitated teaching and learning, technology preparation in teacher education, and e-learning. Lan Li is enthusiastic about integrating her teaching experience and research interests with service opportunities that serve the educational needs of surrounding and global communities.