The Effects of Gamified Teaching on Learning Motivation and Problem-Solving Ability: Evidence from Chinese University Mathematics Classrooms

Li Yuyan[1]*, Sabariah Bte Sharif[1], Ng Giap Weng[2]

[1]Faculty of Education and Sports Studies, Universiti Malaysia Sabah, Sabah, Malaysia

[2]Faculty of Computing and Informatics, Universiti Malaysia Sabah, Sabah, Malaysia

*** Corresponding Author**

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ABSTRACT

This study examined the effects of gamified teaching on learning motivation and problem-solving ability among Chinese university students in a mathematics course. Using a quasi-experimental design, 360 undergraduates were assigned to either a gamified instructional condition or a traditional lecture-based condition over a four-week period. Learning motivation and problem-solving ability were measured using validated instruments, with learning ability and learning styles examined as moderating variables. ANCOVA results indicated that students exposed to gamified teaching demonstrated significantly higher post-intervention motivation and stronger problem-solving performance than those receiving traditional instruction. Moderation analyses revealed that learners with lower prior ability benefited disproportionately from gamified instruction, showing larger gains in both motivational and cognitive outcomes. Additionally, visual and kinesthetic learners exhibited stronger responsiveness to gamified activities. These findings provide empirical evidence that gamified teaching can enhance both motivation and higher-order cognitive skills in higher education, particularly for students who struggle in conventional instructional settings.

Keywords: gamified teaching; learning motivation; problem-solving ability; higher education

INTRODUCTION

The increasing integration of educational technologies into university teaching has led to growing interest in instructional approaches that promote engagement, motivation, and higher-order thinking. In the Chinese higher education context, concerns have intensified over declining student motivation, passive participation, and limited cognitive engagement, particularly in mathematically intensive courses (Chan & Smith, 2024). These challenges are especially prominent in courses where students often struggle with abstraction, cognitive load, and a lack of autonomy (Tian et al., 2020). Traditional lecture-based instruction remains the dominant pedagogical model in many Chinese universities, yet its heavy emphasis on teacher-centered delivery provides limited opportunities for active learning (Zhang et al., 2023). As a result, students frequently experience learning fatigue, reduced confidence, and diminished interest in mathematics-related subjects.

Gamified teaching, defined as the application of game elements such as points, levels, leaderboard rankings, challenges, and immediate feedback in non-game learning contexts, has gained increasing attention as a promising solution to these instructional challenges (Nieto-Escamez & Roldán-Tapia, 2021). Grounded in Self-Determination Theory (SDT), Flow Theory, and Cognitive Load Theory, gamification aims to enhance motivation and engagement by creating learning environments that are interactive, goal-oriented, and psychologically rewarding. SDT, for example, suggests that intrinsic motivation can be fostered by fulfilling the psychological needs of autonomy, competence, and relatedness, all of which can be facilitated by well-structured gamified environments. Flow Theory posits that engagement occurs when there is a balance between the challenge of a task and the individual's ability to meet that challenge, and gamification can adjust the difficulty of tasks to keep learners in this optimal state (Beard, 2015). Cognitive Load Theory underscores the importance of minimizing extraneous cognitive load to allow for deeper cognitive processing, and gamified systems can help achieve this by providing clear feedback and segmented tasks (Bannert, 2002).

Research suggests that well-designed gamified systems can support autonomy, build competence, and promote relatedness, thereby stimulating intrinsic motivation (L. Li et al., 2024). Moreover, by segmenting tasks, providing instant feedback, and offering adaptive challenge levels, gamification may reduce extraneous cognitive load and facilitate deeper processing—key components for effective problem-solving (Kam & Umar, 2018). In this context, gamification offers a method of scaffolding learning in a way that fosters mastery and understanding, particularly in challenging subjects like mathematics, where students often face difficulties due to the abstract and complex nature of the content.

Existing studies in higher education provide evidence that gamification can improve student engagement, self-efficacy, and performance outcomes. For example, interactive quizzes, challenge-based learning tasks, and leaderboard-driven participation have been shown to enhance attention, persistence, and enjoyment in STEM-related courses. Studies indicate that gamification can make learning more engaging, thus reducing feelings of frustration and enhancing a student's sense of progress. However, despite these promising findings, several limitations remain in the current literature. First, many studies have focused on engagement or short-term motivation, with fewer examining the effects of gamification on complex cognitive outcomes such as problem-solving ability. This leaves a gap in understanding the true cognitive benefits of gamification, particularly in subjects that require higher-order thinking and complex reasoning, such as mathematics. Second, individual learner characteristics, especially learning ability and learning styles, are often overlooked, even though students may respond differently to gamified instructional designs. For example, learners with different levels of prior knowledge or cognitive styles may find certain gamified elements more or less effective in helping them process information. Third, although gamification is widely used in Western higher education, empirical evidence from Chinese university mathematics classrooms remains limited.

Learning ability plays a crucial role in shaping students' responses to instructional approaches (S. Li et al., 2024). Students with lower ability levels may particularly struggle with cognitively complex tasks under traditional teaching. Gamification, with its use of feedback-driven task cycles and scaffolded challenge sequences, may be especially effective for these learners by reducing cognitive barriers and enhancing mastery-oriented experiences. The iterative nature of gamified tasks allows learners to progressively build their skills, making it easier for them to tackle more difficult problems as they advance. Similarly, learning styles may influence how students interact with and benefit from gamified environments. Visual and kinesthetic learners, for example, may respond more positively to the multimodal and interactive features inherent in gamified systems. The use of visual elements, animations, and interactive features in gamified tasks can help these students process information more effectively, aligning with their preferred learning styles.

Given these research gaps, this study aims to examine the effects of gamified teaching on learning motivation and problem-solving ability among Chinese university students, while exploring the moderating roles of learning ability and learning styles. Using a quasi-experimental quantitative design with pretest–posttest measures, the study investigates whether gamified teaching produces significantly greater gains than traditional instruction and whether certain groups of students benefit more than others. The research will also examine whether learning styles and ability levels influence how effectively students can engage with and benefit from gamified tasks. By adopting a large sample of 360 students and employing rigorous statistical analyses, the study contributes new evidence to the emerging body of research on gamification in higher education.

The significance of the study is threefold. First, it provides empirical validation of gamified teaching as an effective pedagogical strategy for improving motivation and cognitive performance in mathematics-related learning. The study will add to the growing body of research that supports gamification as a valuable tool in the educational toolbox. Second, it offers new insights into how learner characteristics shape the effectiveness of gamification. Understanding these differential effects is essential for designing inclusive gamified classroom environments. By recognizing that students may have different responses to gamified tasks, educators can tailor instructional designs to better meet the needs of individual learners, fostering a more personalized and inclusive learning experience. Third, the study adds to the limited body of quantitative research conducted in Asian higher education contexts, offering implications for curriculum design, instructional technology integration, and differentiated learning strategies. The findings will help inform the development of instructional approaches that can be effectively scaled across diverse educational settings, particularly in non-Western contexts where the cultural and educational dynamics may differ.

LITERATURE REVIEW

Gamification in Higher Education

Gamification, the application of game-like elements such as points, leaderboards, badges, challenges, and feedback loops in non-game learning contexts, has become an increasingly popular strategy in higher education (Irwanto et al., 2023). Its purpose is to enhance student motivation and engagement by transforming traditional passive learning environments into more interactive, student-centered experiences. Many studies have demonstrated that gamification can lead to improvements in attention, enjoyment, and persistence, particularly in subjects that students find abstract or cognitively challenging, such as mathematics (Murillo-Zamorano et al., 2023). Popular digital platforms like Quizizz, Kahoot, and Classcraft have helped make gamification more accessible by integrating real-time feedback, visual progress indicators, and collaborative tasks, further enabling its adoption in classrooms (Castillo-Parra et al., 2022).

However, despite the promising results, research on gamification has yielded mixed findings. While numerous studies report positive effects on student motivation and academic performance, others suggest that gamification may not be equally effective for all learners. Overly competitive elements, for instance, can create anxiety or disengage some students, while the introduction of superficial game elements may lead to distractions from core learning objectives. These discrepancies highlight the importance of exploring moderating variables, such as individual learner characteristics and cognitive factors, which can influence the effectiveness of gamified teaching strategies.

Learning Motivation and Theoretical Foundations

Learning motivation is widely recognized as a fundamental determinant of academic success, persistence, and cognitive engagement (Sharafi, 2024). A key theoretical framework for understanding how gamification affects motivation is Self-Determination Theory (SDT), which posits that intrinsic motivation is nurtured when three core psychological needs—autonomy, competence, and relatedness—are satisfied. Gamified systems support autonomy by giving students choices regarding task difficulty or learning pathways, which empowers them to take control over their learning process (Cayubit, 2022). Competence is reinforced through feedback loops, points, and progress indicators that allow learners to track their mastery of skills (Chen, 2024). Relatedness is fostered through collaborative challenges or the social comparison driven by leaderboards, which connect learners and motivate them to perform at their best. Flow Theory provides another lens for understanding the cognitive benefits of gamification. According to this theory, flow is achieved when the challenge of a task aligns with a learner's abilities, resulting in a state of deep focus and optimal engagement. Features of gamified environments, such as adaptive difficulty levels and timed challenges, are designed to maintain this challenge-skill balance, which helps sustain flow states and enhances both motivation and cognitive engagement.

Additionally, Cognitive Load Theory offers insight into how gamification can improve learning in complex subjects like mathematics. High levels of intrinsic and extraneous cognitive load often hinder problem-solving performance in mathematics, but gamified designs that break tasks into manageable chunks, provide visual cues, and offer immediate feedback can reduce these cognitive burdens. This reduction in cognitive load enables students to allocate more cognitive resources to understanding complex problems and developing strategies for solving them, thereby improving their overall learning experience.

Learning Styles and Instructional Response

Learning styles refer to individuals' preferred ways of processing information and can significantly affect how they respond to different teaching methods (Mahadevkar et al., 2022). One of the most widely used frameworks for understanding learning preferences is the VARK model, which categorizes learners into visual (V), auditory

(A), reading/writing (R), and kinesthetic (K) types (Noor & Ramly, 2023). Although there is some debate about the predictive validity of learning styles, the concept remains useful in exploring how students engage with various instructional designs.

Gamified learning environments often incorporate multimodal features, such as visual dashboards, animations, point systems, and interactive challenges. These features may be particularly beneficial for visual learners, who thrive on graphical representations and visual progress indicators. Kinesthetic learners, on the other hand, may prefer hands-on, interactive tasks that simulate real-world experiences. Auditory and reading/writing learners, however, might require additional support, such as verbal instructions or written summaries, to make the most of gamified instruction. Given the multimodal nature of gamification, it is plausible that its effectiveness may vary depending on students' learning styles. However, empirical research on the interaction between gamification and learning styles, particularly in STEM fields, remains limited. Understanding these differential effects is crucial for creating inclusive gamified classrooms that accommodate diverse learner needs, enabling all students to benefit from gamified learning environments.

Learning Ability and Differentiated Effects of Gamification

Learning ability plays a central role in how students engage with different instructional strategies (Blackmore et al., 2024). High-ability learners typically have strong foundational knowledge and metacognitive skills that enable them to adapt more readily to new learning environments (Huang et al., 2024). Conversely, low-ability learners may struggle with cognitive overload, lower self-confidence, and higher levels of anxiety, especially in mathematics-intensive courses (Pan et al., 2023).

Gamification can serve as an equalizing tool for low-ability learners by reducing cognitive load through the use of chunked tasks and scaffolded difficulty levels. These learners can also benefit from the instant feedback and visible progress provided by gamified systems, which reinforce their competence and boost their confidence. Moreover, gamified environments often reframe failure as an iterative part of the learning process, which can reduce performance anxiety and encourage persistence. By offering incremental challenges and reward structures, gamification helps these learners stay motivated and continue their learning journey. While several studies suggest that gamification can help low-achieving learners regain motivation and improve performance, there is a notable gap in research systematically examining the role of learning ability as a moderator. This gap is particularly relevant in Chinese higher education, where large class sizes and exam-oriented pressures often exacerbate disparities between high- and low-ability learners.

Gamification and Problem-Solving Ability

Problem-solving is a critical skill in mathematics and STEM education, requiring students to engage in metacognitive regulation, iterative reasoning, and the ability to organize and manipulate information (Yeung et al., 2023). Gamification can potentially enhance problem-solving skills through several mechanisms. For example, the immediate feedback provided by gamified systems helps learners quickly identify and correct errors, while challenge cycles promote iterative reasoning and persistence. Additionally, progression systems reinforce mastery-oriented behaviors, encouraging students to tackle increasingly complex problems.

Research has shown that gamified tasks can externalize cognitive processes by visually representing problem-solving steps and highlighting progress, which may enhance pattern recognition and strategic thinking (Wang et al., 2023). However, most existing studies have focused on short-term effects or small-scale implementations, and few have explored the combined impact of gamification, learning ability, and learning styles on problem-solving outcomes. This research gap underscores the need for more comprehensive studies that investigate how gamification can foster higher-order cognitive skills like problem-solving in diverse learner groups.

Research Gaps

Despite the growing interest in gamification, several significant gaps remain in the literature. First, there is a limited examination of problem-solving outcomes in the context of gamification. While many studies have focused on motivation and engagement, fewer have addressed how gamification influences higher-order cognitive skills such as problem-solving. Second, there is insufficient focus on learner characteristics, particularly learning ability and learning styles, which are often overlooked as moderators in gamification research. Third, there is a lack of large-sample quantitative studies, particularly in the context of Chinese higher education, where large class sizes and exam-oriented systems often introduce unique challenges. Finally, rigorous statistical approaches such as ANCOVA and moderation analyses are underused in gamification research, limiting the clarity of treatment effects. Addressing these gaps could provide a more nuanced understanding of gamification's effectiveness and help guide its future implementation in higher education settings.

RESEARCH METHODOLOGY

Research Design

A quasi-experimental quantitative design was employed in this study with a pretest–posttest non-equivalent groups structure to assess the effects of gamified teaching on learning motivation and problem-solving ability. This design involved two groups of university classes: one receiving the gamified intervention and the other receiving traditional instruction. Pretest scores were used as covariates to account for any initial differences between the groups, and posttest scores served as the outcome measures. To explore potential variations in the effectiveness of the gamified instruction, moderation analyses were conducted to test whether learner characteristics, specifically learning ability and learning styles, influenced the outcomes.

Participants

The study included 360 undergraduate students enrolled in a compulsory mathematics course at a major Chinese university. Cluster sampling was utilized to assign 180 students to the experimental group (gamified teaching) and 180 students to the control group (traditional instruction). The participants came from a range of disciplines, including science, engineering, and business. Baseline assessments and demographic information confirmed that there were no significant pre-intervention differences between the two groups, ensuring comparability at the outset of the study.

Instruments

To measure the key variables in this study, several well-established instruments were employed. Learning motivation was measured using a modified version of the Academic Motivation Scale (AMS), which includes intrinsic motivation, extrinsic motivation, and amotivation subscales. Reliability for this study was high (Cronbach's α = .87). Problem-solving ability was measured using the Problem-Solving Inventory (PSI), assessing metacognitive strategy use, analytical reasoning, and perceived problem-solving effectiveness (Cronbach's α = .82). Learning styles were assessed using the VARK questionnaire, classifying students as visual, auditory, reading/writing, or kinesthetic learners. Learning ability was measured using a university-developed diagnostic mathematics ability test covering reasoning, algebra, and conceptual understanding. Students were categorized into low-, medium-, and high-ability groups.

Gamified Teaching Intervention

The experimental group participated in a four-week gamified instructional module, integrated into the regular mathematics curriculum. The gamified intervention included several key features designed to increase student engagement and motivation. These features were carefully selected based on research that suggests the effectiveness of certain gamification elements in educational settings. Leaderboards were another central element of the gamified intervention. These leaderboards displayed students' rankings in real time, fostering friendly competition and a sense of social comparison. The immediate visibility of their rankings motivated students to keep up with their peers, reinforcing the idea that effort and achievement were recognized. Immediate Feedback was provided after each attempt, allowing students to immediately see the results of their work and understand areas for improvement. This feature is particularly important in helping students correct mistakes and learn from them in a supportive, non-punitive way. Lastly, the intervention included Collaborative Missions, where students worked in small groups to solve problems. T

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Data Collection Procedure

Data were collected in three distinct phases throughout the study. In the Pretest phase, baseline measurements of learning motivation, problem-solving ability, learning styles, and learning ability were gathered from all participants. This initial data collection helped to ensure that there were no significant pre-existing differences between the experimental and control groups and provided a point of reference for later comparisons. The Intervention phase followed, where the experimental group underwent the four-week gamified instructional module while the control group continued with traditional lecture-based teaching. The duration of this phase ensured that enough time was given for the effects of the gamified teaching intervention to manifest. Finally, in the Posttest phase, the same assessments used in the pretest were administered again to measure any changes in learning motivation and problem-solving ability. This three-phase approach allowed for a comprehensive evaluation of how gamified teaching impacted the students' learning outcomes over time.

Data Analysis

The collected data were analyzed using SPSS, a widely used statistical software package. ANCOVA (Analysis of Covariance) was employed to examine between-group differences in posttest scores for learning motivation and problem-solving ability while controlling for pretest scores. In addition to ANCOVA, Two-Way ANOVA and Hierarchical Moderation Analyses were used to explore the interactions between the teaching method and the moderators of learning ability and learning styles. These analyses helped to uncover whether certain groups of students benefited more from the gamified approach than others. By using these advanced statistical techniques, the study aimed to provide a more detailed understanding of the factors that influence the success of gamified teaching in higher education.

RESULTS AND DISCUSSION

Preliminary Analysis

Prior to hypothesis testing, preliminary analyses were conducted to examine the reliability, distributional properties, and baseline equivalence of the data. All measurement scales demonstrated strong internal consistency, with Cronbach’s alpha values ranging from .82 to .96, indicating satisfactory reliability for subsequent analyses. Examination of skewness and kurtosis values showed that all variables fell within the acceptable range of ±1, supporting the assumption of normality and the appropriateness of parametric statistical tests.

Table 1: Results of Preliminary Analysis

Group	N	Pre-Motivation (M ± SD)	Post-Motivation (M ± SD)	Pre-Problem-Solving (M ± SD)	Post-Problem-Solving (M ± SD)
Gamified Teaching	180	3.42 ± 0.51	4.12 ± 0.48	3.36 ± 0.49	4.01 ± 0.46
Traditional Teaching	180	3.40 ± 0.50	3.58 ± 0.52	3.34 ± 0.47	3.61 ± 0.50

Independent-samples comparisons of pretest scores revealed no significant differences between the gamified teaching group and the traditional teaching group in terms of learning motivation or problem-solving ability ($p > .05$). This confirmed that the two groups were comparable at baseline. Descriptive statistics further illustrated similar pretest means across groups, while posttest means suggested noticeable improvements in both outcomes for the gamified group. As shown in Table 1, students exposed to gamified teaching exhibited larger gains in motivation (from M = 3.42 to M = 4.12) and problem-solving ability (from M = 3.36 to M = 4.01) compared with those receiving traditional instruction. These preliminary results provided initial evidence supporting the effectiveness of the gamified intervention and justified further inferential analyses.

Effects of Gamified Teaching on Learning Motivation

To examine the effect of gamified teaching on learning motivation, an ANCOVA was conducted with posttest motivation as the dependent variable, instructional method as the independent variable, and pretest motivation as the covariate. The results in Table 2 revealed a significant main effect of instructional method, $F(1, 357) = 59.99$, $p < .001$, with a partial η^2 of .156. This indicates that, after controlling for baseline motivation, students in the gamified teaching group reported significantly higher levels of learning motivation than those in the traditional teaching group.

The effect size (partial $\eta^2 = .156$) can be interpreted as medium to large, suggesting that gamified teaching produced substantial motivational benefits beyond those achieved through conventional lecture-based instruction. This finding supports the assumption that gamified elements such as points, feedback, and interactive challenges can effectively enhance students' motivational engagement in mathematics learning environments.

Table 2 ANCOVA Results for Learning Motivation and Problem-Solving Ability

Dependent Variable	Source	F	p	Partial η^2
Learning Motivation	Teaching Method	59.99	< .001	.156
Problem-Solving Ability	Teaching Method	23.61	< .001	.063

Effects of Gamified Teaching on Problem-Solving Ability

A similar ANCOVA was performed to assess the impact of gamified teaching on problem-solving ability, controlling for pretest problem-solving scores. The analysis indicated a significant main effect of instructional method, $F(1, 357) = 23.61$, $p < .001$, with a partial η^2 of .063. Students in the gamified teaching group outperformed their peers in the traditional group on posttest problem-solving measures, even after accounting for initial differences.

Although the effect size was smaller than that observed for learning motivation, the partial η^2 value of .063 still represents a meaningful medium effect. This result suggests that gamified teaching not only enhances students' affective engagement but also contributes to improvements in higher-order cognitive skills. Features such as immediate feedback, iterative challenge cycles, and mastery-oriented progression appear to support more effective problem-solving processes in mathematics.

Moderating Role of Learning Ability

Table 3. Moderating Effects of Learning Ability and Learning Styles

Moderator	Outcome Variable	Statistic	p	Key Finding
Learning Ability	Motivation	$\beta = .24–.30$	< .01	Low-ability learners benefited most
Learning Ability	Problem-Solving	$\beta = .28–.36$	< .01	Compensatory effect observed
Learning Styles	Motivation	$F(3,352) = 6.44$	< .001	Visual & kinesthetic learners showed larger gains
Learning Styles	Problem-Solving	Significant	< .01	Multimodal alignment advantage

To investigate whether learning ability moderated the effect of gamified teaching on learning motivation, hierarchical moderation analyses were conducted. The interaction between instructional method and learning ability was statistically significant in Table 3, with standardized coefficients ranging from $\beta = .24$ to .30 ($p < .01$). Simple slope analyses further clarified this interaction pattern, showing that students with low learning ability experienced the largest motivational gains, followed by those with medium ability, while high-ability students demonstrated smaller but still significant improvements. These findings indicate that gamified teaching functioned as a motivational equalizer, particularly benefiting students who typically struggle in traditional mathematics classrooms. By providing scaffolded challenges, visible progress, and frequent feedback, the gamified environment appeared to reduce motivational barriers for lower-ability learners and encourage sustained engagement.

Learning ability also significantly moderated the relationship between instructional method and problem-solving ability. The interaction effects were significant in Table 3, with coefficients ranging from $\beta = .28$ to $.36$ ($p < .01$). Consistent with the motivation results, low-ability students showed the greatest gains in problem-solving performance under gamified instruction, whereas medium- and high-ability students demonstrated more moderate improvements. This pattern suggests that gamified tasks helped lower-ability learners manage cognitive demands more effectively, likely by reducing extraneous cognitive load and encouraging persistence through multi-step problems. The results support the compensatory role of gamification in narrowing performance gaps between students with different levels of prior ability.

Moderating Role of Learning Styles

A two-way ANOVA was conducted to examine the interaction between instructional method and learning styles on learning motivation. The results in Table 3 revealed a significant interaction effect, $F(3, 352) = 6.44$, $p < .001$, with a partial η^2 of .052. Post hoc analyses indicated that visual and kinesthetic learners exhibited the largest motivational increases in the gamified teaching condition, whereas auditory and reading/writing learners showed smaller, though still positive, gains. This finding suggests that the motivational impact of gamification is partly dependent on how well its design aligns with students' preferred modes of information processing. Visual dashboards, progress indicators, and interactive elements appear particularly effective for learners who favor visual and hands-on experiences.

A similar interaction pattern emerged for problem-solving ability. Visual and kinesthetic learners demonstrated the strongest improvements in problem-solving performance in the gamified environment, while auditory and reading/writing learners also showed significant but comparatively smaller gains. These results indicate that the multimodal and interactive nature of gamified instruction provides an advantage for learners whose styles align with visual and kinesthetic features. Overall, the moderation analyses confirmed that learning styles significantly influenced the effectiveness of gamified teaching, highlighting the importance of considering learner diversity when designing gamified instructional environments.

DISCUSSION

The results showed that gamified teaching significantly enhanced students' learning motivation, which is consistent with a growing body of research highlighting the motivational potential of game-based elements in educational contexts. From the perspective of Self-Determination Theory (SDT), the observed motivational gains can be attributed to the extent to which the gamified environment satisfied students' basic psychological needs. Autonomy was supported by allowing students to choose challenge levels and progress at their own pace, which helped them feel a greater sense of control over their learning. Competence was reinforced through points, immediate corrective feedback, and visual progress indicators, all of which made learning progress more transparent and achievable. Relatedness was strengthened through collaborative missions and leaderboard-based social comparison, which encouraged peer interaction and a shared sense of participation. These mechanisms collectively transformed mathematics learning from a passive and often anxiety-inducing experience into a more engaging and rewarding process. The medium-to-large effect size (partial $\eta^2 = .156$) indicates that the motivational benefits of gamified instruction were not only statistically significant but also educationally meaningful. Compared with traditional instruction, gamified environments appear to offer richer motivational affordances that can effectively re-engage students who might otherwise feel disengaged or discouraged in mathematics courses.

In addition to motivational gains, gamified teaching also led to significant improvements in problem-solving ability. This finding aligns well with Flow Theory, which emphasizes the importance of maintaining a balance between task challenge and learner skill to promote deep cognitive engagement. Through adaptive difficulty levels, interactive feedback, and rapid iteration cycles, gamified tasks encouraged sustained focus, greater persistence, and repeated refinement of problem-solving strategies. Students were more willing to engage in trial-and-error learning, which is essential for developing analytical thinking in mathematics. Cognitive Load Theory provides further explanatory power for these results. Mathematics problem-solving often involves high intrinsic cognitive load, and poorly structured instruction can exacerbate extraneous load. The gamified design reduced unnecessary cognitive burden by chunking complex tasks into smaller steps, visually organizing progress, and offering immediate feedback that clarified errors. As a result, students were able to allocate more cognitive resources to higher-order reasoning and metacognitive regulation. These findings suggest that gamification functions not merely as a motivational enhancement but also as a cognitively supportive instructional strategy capable of improving analytical performance in demanding academic contexts.

One of the most important findings of this study was that students with lower prior learning ability benefited disproportionately from gamified teaching. This result supports the view that gamification can serve as a compensatory instructional mechanism, particularly for learners who struggle under traditional teaching approaches. For lower-ability students, scaffolded challenge levels helped reduce task anxiety and made complex problems feel more manageable. Immediate feedback enabled faster error correction and more effective strategy adjustment, while reward structures encouraged persistence and reframed failure as a natural part of the learning process. Additionally, visual cues and progress indicators helped externalize cognitive processes, supporting comprehension and strategic thinking. These findings contribute to the limited quantitative literature demonstrating that gamification can help reduce learning disparities. In the context of university mathematics courses, where differences in prior knowledge and ability are often pronounced, gamified teaching may offer a practical pathway toward more equitable learning outcomes by providing differentiated support without stigmatizing lower-performing students.

Learning styles were used in this study as analytical categories to explore differential instructional responses rather than as fixed or deterministic traits. The results indicated that learning styles moderated the effects of gamified instruction, with visual and kinesthetic learners showing the strongest improvements in both learning motivation and problem-solving ability. This pattern is not surprising, as gamified environments typically emphasize visual dashboards, animations, interactive tasks, and fast-paced decision-making, which align closely with visual and kinesthetic learning preferences. At the same time, auditory and reading/writing learners demonstrated smaller, though still significant, gains. This suggests that while gamification is broadly effective, its design may inadvertently privilege certain modalities unless additional supports are provided. Incorporating verbal explanations, reflective discussions, and structured textual summaries into gamified activities may help ensure that learners with different preferences can benefit equally. Overall, these findings underscore the importance of inclusive gamification design, in which multiple modalities are intentionally integrated to accommodate diverse learners and maximize the instructional potential of gamified teaching.

CONCLUSION

This study examined the effects of gamified teaching on learning motivation and problem-solving ability among Chinese university students in a mathematics course, with particular attention to the moderating roles of learning ability and learning styles. The findings indicate that gamified teaching significantly outperformed traditional instruction in enhancing both motivational and cognitive outcomes. Specifically, gamified instruction fostered a more engaging and autonomy-supportive learning environment, leading to higher levels of learning motivation and stronger problem-solving performance. Importantly, the results revealed clear differential effects across learner characteristics: students with lower learning ability benefited the most from gamified tasks, suggesting a compensatory effect, while visual and kinesthetic learners showed stronger positive responses than other learning style groups. By extending gamification research to the context of Chinese higher education and empirically demonstrating its impact on both motivation and problem-solving ability, this study provides robust evidence that gamified teaching is an effective pedagogical strategy for mathematics courses where student engagement and analytical performance are persistent challenges.

Based on these findings, several practical and theoretical implications can be drawn. From a practical perspective, educators and instructional designers are encouraged to adopt multimodal gamified designs that integrate visual representations, interactive tasks, and collaborative activities to accommodate diverse learning preferences. The use of immediate feedback, clear progression systems, and adaptive challenge levels can reinforce students' sense of competence and support self-regulated learning, particularly for low-ability learners who are more vulnerable to cognitive overload and learning anxiety. Collaborative missions and social interaction features should also be incorporated to enhance relatedness and peer motivation, while carefully balancing competition and cooperation. From a theoretical standpoint, the study advances understanding of how gamified teaching operationalizes key principles from Self-Determination Theory, Flow Theory, and Cognitive Load Theory in authentic classroom settings. Furthermore, the instructional design principles identified in this study—such as adaptive challenge cycles, frequent feedback loops, clear reward structures, and scaffolded support—offer a data-driven framework for universities seeking to implement inclusive and effective gamified learning environments.

Despite its contributions, this study has several limitations that suggest areas for future research. First, the four-week intervention limits conclusions about the long-term sustainability of gamification effects; longer implementations could assess durability and transfer effects. Second, conducted within a single institutional context, the study's findings may not be widely applicable; replication across different universities, disciplines, and cultural settings is needed. Third, the quasi-experimental design used non-randomized group assignment; randomized controlled trials would provide stronger causal inference. Additionally, the use of the VARK framework to measure learning styles has been debated, so future research could employ more nuanced or multimodal assessments. Finally, the study focused on quantitative outcomes, and incorporating qualitative approaches like interviews or learning analytics could provide deeper insights into students' cognitive and emotional experiences. Future research could also explore adaptive gamification designs, intelligent feedback systems, and cross-disciplinary applications to improve the effectiveness and inclusiveness of gamified teaching.

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