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Investigating the Impact of a Mobile Game-Based AI-Enhanced Learning Strategy on L2 Students' Motivation and Achievement

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Abstract

The rapid evolution of digital technologies has transformed language education; however, the integrated application of mobile learning, game-based learning, and artificial intelligence (AI) in secondary school second language acquisition remains insufficiently explored. Addressing this gap, the present study investigates the effectiveness of a mobile game-based AI-enhanced learning strategy in improving students' English learning motivation and academic achievement. A quasi-experimental design was employed involving 78 high school students over a 12-week period, with participants assigned to either an experimental group using the developed system or a control group receiving traditional instruction. Quantitative data were collected through pretest–posttest measures and a validated motivation questionnaire, complemented by qualitative feedback. The results revealed that the proposed approach significantly enhanced students' motivation across multiple dimensions and led to higher learning achievement compared to conventional methods. Notably, the system was particularly effective in engaging students who initially lacked interest in learning English, as it increased their willingness to participate and enjoyment in learning activities. However, its effectiveness was less pronounced among students with low preference for game-based learning, highlighting the role of individual differences. The novelty of this study lies in its integrative framework, combining mobile accessibility, gamified interaction, and AI-driven personalization within a single learning environment. These findings contribute to the growing body of technology-enhanced language learning research and offer practical implications for designing adaptive, engaging, and learner-centered instructional systems in diverse educational contexts.

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1. Introduction

The rapid digitalization of education has fundamentally reshaped how knowledge is accessed, constructed, and experienced in the 21st century. Among the most influential developments, mobile learning has emerged as a transformative pedagogical approach that enables flexible, ubiquitous, and learner-centered educational experiences. Through the integration of wireless networks and Internet-based platforms, learners can access educational resources anytime and anywhere, thereby supporting continuous and personalized learning (Naveed et al., 2023; Goksu, 2021; Carrión-Candel & Colmenero, 2022; Lai, 2020; Kumar & Sharma, 2020). This shift reflects a broader transition toward learner autonomy, where students actively regulate their learning processes according to their needs and preferences (Moya & Camacho, 2021).

In language education, this transformation has led to the growing adoption of Mobile-Assisted Language Learning (MALL), which leverages mobile technologies to facilitate language acquisition in flexible and contextually meaningful ways (Figueiredo, 2023). Prior research has demonstrated that MALL enhances accessibility, engagement, and personalized learning by enabling just-in-time access to instructional content (Gupta et al., 2021). Applications such as Duolingo further illustrate how mobile platforms can incorporate interactive and game-like features to support language retention (Davudova & Türel, 2022). However, despite these advantages, existing studies have primarily emphasized technological affordances, with limited attention to how mobile learning can be pedagogically optimized to sustain motivation and improve learning outcomes.

Alongside mobile learning, game-based learning has been widely recognized as an effective approach for enhancing learner engagement and motivation. By integrating elements such as challenges, feedback, and rewards, game-based learning transforms traditional instruction into interactive and immersive experiences (Behl et al., 2022; Carrión-Candel & Colmenero, 2022; Pham et al., 2021; Silva et al., 2020). Empirical evidence suggests that such approaches promote self-regulated learning, improve problem-solving skills, and increase knowledge retention (Dele-Ajayi et al., 2019; Yomeldi et al., 2019). Nevertheless, the integration of game-based learning within mobile environments is often limited, and its alignment with language learning objectives remains insufficiently explored.

More recently, artificial intelligence (AI) has introduced new possibilities for adaptive and personalized learning. AI technologies can analyze learner performance, provide real-time feedback, and deliver tailored learning experiences, thereby enhancing both learning efficiency and engagement (Belda-Medina & Kokošková, 2023; Jin et al., 2023; Moundridou et al., 2024; Moya & Camacho, 2024). In language learning contexts, AI can function as an intelligent tutor and interactive assistant. However, prior findings on its impact on learner motivation remain inconsistent, suggesting that its effectiveness depends on contextual and design factors (Guan et al., 2024). Importantly, the combined integration of mobile learning, game-based learning, and AI remains underexplored, particularly in secondary education settings.

This gap is particularly relevant in contexts such as Taiwan, where English is widely recognized as a crucial global language, yet many students perceive learning English as monotonous and challenging. Traditional instructional practices, which rely heavily on repetitive exercises, have been shown to limit engagement and promote passive learning behaviors (Rigby, 2021; Hsieh & Tsai, 2017; Yang, 2023). As a result, students often become dependent on teacher guidance and struggle to develop autonomous learning skills. These challenges highlight the need for more engaging, adaptive, and learner-centered instructional approaches.

To address these limitations, the present study proposes a mobile game-based AI-enhanced learning strategy that integrates the strengths of mobile learning, game-based learning, and artificial intelligence into a unified framework. The novelty of this study lies in its holistic approach, which examines the combined effects of these three pedagogical components while also incorporating individual difference variables, including interest, enjoyment, and time spent. By doing so, this study provides a more comprehensive understanding of how learners interact with technology-enhanced environments.

Accordingly, this study aims to examine the effectiveness of the proposed approach in improving students' English learning motivation and academic achievement, as well as to investigate the role of individual differences in shaping learning outcomes. The study is guided by the following research questions:

RQ1: Does the mobile game-based AI-enhanced English learning strategy influence learning motivation?
RQ2: Does the mobile game-based AI-enhanced English learning strategy affect learning achievement?
RQ3: Do individual differences affect students' English learning motivation?
RQ4: Do individual differences influence students' English learning achievement?

By addressing these questions, this study contributes to the advancement of technology-enhanced language learning by providing empirical evidence on the effectiveness of integrating mobile learning, gamification, and AI. The findings are expected to offer both theoretical insights and practical implications for the design of more adaptive, engaging, and learner-centered language learning environments.

2. Method

2.1 Research Design

This study employed a pretest–posttest quasi-experimental design to examine the effectiveness of a mobile game-based AI-enhanced English learning strategy (Chen et al., 2023). Two intact groups were assigned as the experimental group and the control group. Both groups received identical classroom instruction delivered by the same teacher to control for instructional variability.

The experiment was conducted over a 12-week period. During the first six weeks, both groups followed the same instructional activities. In the final six weeks, the experimental group engaged in self-

directed learning using the developed mobile system, while the control group completed traditional worksheet-based tasks.

2.2 Participants

The participants consisted of 78 tenth-grade students from a senior vocational high school in Taiwan. Two intact classes were assigned as the control group (n = 40) and the experimental group (n = 38). Participation was voluntary, and informed consent was obtained from all participants prior to data collection.

2.3 Variables

This study included one independent variable (learning strategy), two dependent variables (learning motivation and learning achievement), and individual difference variables, namely interest, enjoyment, and time spent. The operational definitions of these variables are presented in Table 1.

Table 1. Operational Definition of Individual Differences

Variable	Option and Statement
Interest in learning English	IN- (student is not interested in learning English), IN (student does not have specific interest), IN+ (student is interested in learning English)
Interest in playing games	IN- (student is not interested in playing games), IN (student does not have specific interest), IN+ (student is interested in playing games)
Enjoyment when playing the System	EN- (student does not enjoy), EN (neutral), EN+ (student enjoys playing the System)
Time spent playing the System per week	≤3 hours, 3–7 hours, ≥7 hours
Time spent playing games per week	≤7 hours, 7–14 hours, ≥14 hours

2.4 Materials and Instruments

2.4.1 Instructional Design

The instructional program consisted of a 12-week English course covering fundamental language components, including vocabulary, grammar, phrases, and sentence structures. Each week included four 50-minute sessions, and both groups followed the same curriculum during classroom instruction.

During the final six weeks, the experimental group used a mobile game-based AI-enhanced learning system to review course content, while the control group completed equivalent worksheet-based tasks. The system integrated game-based learning elements with AI-driven personalization, enabling adaptive task difficulty and real-time feedback based on students' performance.

2.4.2 Instruments

The instruments used in this study are summarized in Table 2.

Table 2. Summary of Research Instruments

Instrument	Purpose	Items	Scale	Reliability
Pretest/Posttest	Measure English learning achievement	–	0–100	Content validated
MSLQ (adapted)	Measure learning motivation	25	7-point Likert	α = .936
Interview	Explore students' perceptions	–	Semi-structured	–

The pretest and posttest were developed by experienced English teachers to ensure content validity and alignment with the curriculum. Learning motivation was measured using an adapted version of the MSLQ (Pintrich et al., 1991). The reliability of the questionnaire was confirmed, with Cronbach's α values exceeding .700 (Nunnaly, 1978) and an overall reliability of .936.

2.5 Data Collection Procedure

Data collection was conducted in four stages. First, students completed the pretest and the motivation questionnaire. Second, the 12-week instructional intervention was implemented. Third, students completed the posttest and the motivation questionnaire. Finally, semi-structured interviews were conducted to collect qualitative data on students' learning experiences.

2.6 Data Analysis

Quantitative data were analyzed using inferential statistical methods. Independent samples t-tests were conducted to compare differences between the experimental and control groups, while paired-samples t-tests were used to examine changes within groups over time. One-way ANOVA was employed to analyze the effects of individual difference variables. All analyses were conducted at a significance level of $p < .050$. Qualitative data from the interviews were analyzed using thematic analysis to identify patterns in students' responses.

3. Results

3.1 Effects of Learning Strategy on Learning Motivation (RQ1)

An independent samples t-test was conducted to examine the effect of the mobile game-based AI-enhanced learning strategy on students' English learning motivation. The results are presented in Table 4.

Table 4. T-test Results for Learning Motivation Across Groups

Dimension	Group	N	Mean	S.D.	t value	Sig.
Intrinsic goal orientation	Control	40	17.90	3.095	-5.654	.000
	Experimental	38	22.11	3.470		
Extrinsic goal orientation	Control	40	19.53	2.708	-3.815	.000
	Experimental	38	22.24	3.499		
Task value	Control	40	27.35	3.939	-3.038	.003
	Experimental	38	30.55	5.244		
Control of learning beliefs	Control	40	17.43	3.296	-4.389	.000
	Experimental	38	21.05	3.986		
Self-efficacy for learning and performance	Control	40	28.60	3.720	-5.149	.000
	Experimental	38	35.13	6.929		

The results revealed statistically significant differences between the experimental and control groups across all five motivational dimensions ($p < .01$). Across all dimensions, the experimental group consistently demonstrated higher mean scores than the control group.

Notably, the largest differences were observed in self-efficacy for learning and performance ($\Delta M = 6.53$) and intrinsic goal orientation ($\Delta M = 4.21$), indicating substantial improvements in students' confidence and intrinsic engagement. Comparatively smaller, yet still significant, differences were found in task value ($\Delta M = 3.20$) and extrinsic goal orientation ($\Delta M = 2.71$). Overall, the results demonstrate a consistent pattern in which the experimental group outperformed the control group across all motivational constructs.

3.2 Effects of Learning Strategy on Learning Achievement (RQ2)

Independent samples t-tests were conducted to compare students' English learning achievement between the two groups. The results are presented in Table 5.

Table 5. T-test Results for Learning Achievement

Test	Group	N	Mean	S.D.	t value	Sig.
Pretest	Control	40	57.28	7.331	1.086	.389
	Experimental	38	56.47	5.520		
Posttest	Control	40	63.80	10.062	-5.149	.000

Experimental	38	67.42	8.278

The pretest results indicated no statistically significant difference between the two groups ($p = .389$), suggesting comparable baseline proficiency. The mean scores of both groups were closely aligned, with a difference of less than one point.

In contrast, the posttest results showed a statistically significant difference ($p < .001$), with the experimental group achieving higher scores than the control group. The experimental group demonstrated a greater increase in mean scores from pretest to posttest ($\Delta M = 10.95$) compared to the control group ($\Delta M = 6.52$), indicating a stronger improvement in learning achievement.

3.3 Descriptive Statistics of Individual Differences

Descriptive statistics for students' interest and enjoyment are presented in Table 6.

Table 6. Descriptive Statistics of Interest and Enjoyment (Experimental Group)

Category	Interest in Learning English		Interest in Playing Games		Enjoyment when Playing the System	
	N	%	N	%	N	%
Low	13	34.2	3	7.9	4	10.5
Moderate	11	28.9	11	28.9	9	23.7
High	14	36.8	24	63.2	25	65.8

The descriptive results indicate that a majority of students reported high levels of interest in playing games (63.2%) and high enjoyment when using the System (65.8%), whereas interest in learning English was more evenly distributed across categories. Table 7 presents the distribution of time spent.

Table 7. Descriptive Statistics of Time Spent (Experimental Group)

Time Category	System (N)	%	Games (N)	%
Low	12	31.6	14	36.8
Medium	19	50.0	9	23.7
High	7	18.4	15	39.5

Most students spent a moderate amount of time (50.0%) using the System, while time spent playing games showed a more varied distribution, with a relatively larger proportion in the high category.

3.4 Effects of Individual Differences on Learning Motivation (RQ3)

A one-way ANOVA was conducted to examine the effects of individual differences on learning motivation (Table 8).

Table 8. ANOVA Results for Learning Motivation

Variable	Group	Mean	S.D.	F	Post hoc
Interest in learning English	IN-	124.01	3.567	5.540*	IN+ > IN, IN-
	IN	125.55	3.641		
	IN+	139.26	4.992		
Interest in playing games	IN-	114.34	1.831	5.446*	IN+ > IN, IN-
	IN	124.27	4.067		
	IN+	136.31	4.615		
Enjoyment	EN-	123.53	3.349	6.463*	EN+ > EN, EN-
	EN	120.55	3.262		
	EN+	141.30	4.699		
Time (System)	HS3-	124.33	3.990	6.102*	H7+ > H3+, H3-
	HS3+	128.69	4.233		
	HS7+	149.14	4.104		
Time (Games)	HG7-	127.43	4.758	.815	–
	HG7+	130.00	3.895		
	HG14+	135.13	4.882		

The results showed that students with higher levels of interest, enjoyment, and time spent using the System consistently demonstrated higher motivation scores. A clear upward trend was observed across categories (e.g., IN- → IN → IN+), indicating a positive relationship between these variables and motivation. In contrast, time spent playing games did not show a statistically significant effect.

3.5 Effects of Individual Differences on Learning Achievement (RQ4)

A one-way ANOVA was conducted to examine the effects of individual differences on learning achievement (Table 9).

Table 9. ANOVA Results for Learning Achievement

Variable	Group	Mean	S.D.	F	Post hoc
Interest in learning English	IN-	58.46	6.398	43.387*	IN+ > IN > IN-
	IN	69.00	1.612		
	IN+	74.64	4.012		
Interest in playing games	IN-	63.00	6.557	10.064*	IN+ > IN, IN-
	IN	60.55	7.815		
	IN+	71.21	6.283		
Enjoyment	EN-	50.00	3.367	55.667*	EN+ > EN > EN-
	EN	62.78	2.819		
	EN+	71.96	4.596		
Time (System)	HS3-	60.25	7.021	11.702*	H7+ > H3+ > H3-
	HS3+	69.63	5.718		
	HS7+	74.00	8.000		
Time (Games)	HG7-	66.14	6.689	1.023	–
	HG7+	70.89	3.822		
	HG14+	66.67	9.985		

The findings revealed a consistent pattern in which higher levels of interest, enjoyment, and time spent using the System were associated with higher learning achievement scores. The strongest effect was observed for enjoyment (F = 55.667), followed by interest in learning English (F = 43.387). Similar to motivation, time spent playing games did not show a significant effect.

4. Discussion

This study examined the effectiveness of a mobile game-based AI-enhanced learning strategy in improving students' English learning motivation and achievement, as well as the influence of individual differences on these outcomes. The findings provide clear evidence that the proposed approach significantly enhances both motivational and academic dimensions of language learning.

First, the results indicate that the mobile game-based AI-enhanced strategy significantly improved students' learning motivation across all measured dimensions, including intrinsic and extrinsic goal orientation, task value, control of learning beliefs, and self-efficacy. These findings suggest that integrating mobile accessibility, game-based interaction, and AI-driven personalization can create a more engaging and supportive learning environment (Abbas et al., 2025). In particular, improvements in intrinsic motivation and self-efficacy highlight the role of interactive and adaptive learning experiences in fostering deeper learner engagement. This finding is consistent with prior research on MALL and game-based learning, which emphasizes their positive effects on motivation (Alade et al., 2020; Criollo-C et al., 2021; Behl et al., 2022; Pham, Nguyen & Le, 2021; Silva et al., 2020), as well as studies highlighting the benefits of AI-driven personalization (Belda-Medina & Kokošková, 2023; Jin et al., 2023; Moundridou, Matzakos & Doukakis, 2024).

Second, the findings demonstrate that the proposed strategy significantly improved students' English learning achievement. Although both groups showed improvement, the experimental group achieved greater gains, indicating that the integration of mobile learning, gamification, and AI can enhance learning effectiveness beyond traditional approaches. This result supports previous studies on the effectiveness of MALL and game-based learning in improving academic performance (Gupta et al., 2021; Figueiredo,

2023; Dele-Ajayi et al., 2019; Yomeldi et al., 2019), while extending them by demonstrating the added value of combining these approaches within a single learning framework.

Third, individual differences were found to play a significant role in shaping learning outcomes. Students with higher levels of interest, enjoyment, and time spent using the system demonstrated higher motivation and achievement. These findings highlight the importance of affective and behavioral engagement in technology-enhanced learning environments (Huang et al., 2026; Wang et al., 2026). In particular, the strong influence of enjoyment supports prior research emphasizing the role of positive emotions in sustaining motivation and improving learning performance (Pekrun et al., 2011; Liu & Chu, 2010). Similarly, the effect of time spent aligns with findings that increased engagement in meaningful learning activities leads to improved outcomes (Goh, 2026; Kostiainen et al., 2026; Sandberg et al., 2011).

Interestingly, time spent playing games outside the system did not significantly influence learning outcomes, suggesting that engagement alone is insufficient without appropriate pedagogical design. This finding reinforces the importance of aligning game mechanics with learning objectives, as emphasized in previous studies (Dele-Ajayi et al., 2019; Maiti, 2026). It also indicates that structured and goal-oriented learning environments are more effective than unstructured gaming activities.

Taken together, these findings address a key gap in the literature. While previous studies have examined mobile learning, game-based learning, and AI-enhanced learning independently, few have explored their combined effects within a unified framework. The present study contributes to the field by demonstrating that integrating these approaches can produce complementary and reinforcing effects on both motivation and achievement. The novelty of this study lies in its holistic design, which integrates mobile learning, gamification, and AI while incorporating individual difference variables to provide a more comprehensive understanding of learner engagement. This integrative approach offers a more nuanced perspective on how cognitive, affective, and behavioral factors interact within technology-enhanced learning environments (Adams, 2026).

From a practical perspective, the findings suggest that educators should adopt adaptive and learner-centered approaches that combine interactivity, personalization, and engagement. Designing learning systems that account for students' interests and enjoyment is essential for maximizing both motivation and achievement. Furthermore, AI technologies can be leveraged to provide personalized feedback and support, thereby enhancing learning effectiveness.

Despite these contributions, several limitations should be acknowledged. The study was conducted with a relatively small sample from a single educational context, which may limit generalizability. Even within a small sample, it would be beneficial to examine the effects further on specific user demographics such as the elderly (Chusri et al., 2026). In addition, the duration of the intervention was relatively short, and longer-term effects were not examined. Future research is therefore recommended to investigate the long-term impact of mobile game-based AI-enhanced learning in diverse educational settings, explore additional learner variables, and further refine AI-driven adaptive mechanisms to better support individual learning needs (Čep et al., 2026)

5. Conclusion

This study demonstrates that a mobile game-based AI-enhanced English learning strategy can significantly improve students' learning motivation and academic achievement, particularly by strengthening intrinsic engagement and self-efficacy. The key contribution lies in its integrative framework, which combines mobile learning, gamification, and artificial intelligence, addressing a critical gap in prior research that has largely examined these elements separately. The findings further highlight that individual differences, especially interest and enjoyment, play a crucial role in determining the effectiveness of technology-enhanced learning, indicating that successful implementation depends not only on technological design but also on learners' affective engagement. From a practical perspective, the results suggest that educators should adopt adaptive and learner-centered systems that integrate interactivity and personalization to sustain student engagement. However, the study is limited by its relatively small sample size and short intervention duration, as well as potential novelty effects associated with AI-based learning. Future research should examine the long-term effectiveness of such approaches across diverse educational contexts, involve larger and more varied populations, and further refine AI-driven adaptive mechanisms to better accommodate individual learning needs. These efforts will be essential for advancing the development of more effective and scalable language learning technologies.

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