Salud, Ciencia y Tecnología. 2026; 6:2605
doi: 10.56294/saludcyt20262605

ORIGINAL

From Confidence to Enjoyment: How Perceived Enjoyment and Self-Efficacy Shape Engineering Students' Intention to Adopt Mobile-Based Gamification Learning

De la confianza al disfrute: cómo el disfrute percibido y la autoeficacia influyen en la intención de los estudiantes de ingeniería de adoptar el aprendizaje gamificado basado en dispositivos móviles

Habibullah[1], Doni Tri Putra Yanto[1], Oriza Candra[1], Refi Revina[2], Agariadne Dwinggo Samala[3], Soha Rawas[4], Juan Luis Cabanillas-García[5], Juana Maria Arcelus-Ulibarrena[6]

[1]Universitas Negeri Padang, Electrical Engineering Department. Padang, Indonesia.
[2]Universitas Riau, Department of Mathematics. Riau, Indonesia.
[3]Universitas Negeri Padang, Electronic Engineering Department. Padang, Indonesia.
[4]Beirut Arab University, Department of Mathematics and Computer Science. Beirut, Lebanon.
[5]University of Extremadura, Department of Education Sciences. Spain.
[6]University of Naples Parthenope, Department of Economic and Legal Studies. Naples, Italy.

Cite as: Habibullah, Putra Yanto DT, Candra O, Revina R, Samala AD, Rawas S, et al. From Confidence to Enjoyment: How Perceived Enjoyment and Self-Efficacy Shape Engineering Students' Intention to Adopt Mobile-Based Gamification Learning. Salud, Ciencia y Tecnología. 2026; 6:2605. https://doi.org/10.56294/saludcyt20262605

Submitted: 29-08-2025 **Revised:** 22-10-2025 **Accepted:** 10-12-2025 **Published:** 01-01-2026

Editor: Prof. Dr. William Castillo-González

Corresponding author: Doni Tri Putra Yanto

ABSTRACT

Introduction: digital transformation in the Education 4.0 era has significantly reshaped higher education, including engineering education. In alignment with Sustainable Development Goal (SDG) 4: Quality Education, mobile-based gamification learning (MobGam) has emerged as an innovative approach to enhance learning quality. This study aims to analyze students' behavioral intention (BI) to adopt MobGam by extending the Technology Acceptance Model (TAM) with two external constructs: Self-Efficacy (SE) and Perceived Enjoyment (PE).
Method: a quantitative survey was conducted with 127 Industrial Electrical Engineering students in Indonesia. Data were collected using a five-point Likert-scale questionnaire and analyzed using Partial Least Squares-Structural Equation Modeling (PLS-SEM) to evaluate both measurement and structural models.
Results: the findings show that PE significantly enhances both Perceived Ease of Use (PEU) (β = 0,553, p = 0,001) and Perceived Usefulness (PU) (β = 0,301, p = 0,003). SE also demonstrates a strong positive effect on PEU (β = 0,424, p = 0,001) and PU (β = 0,296, p = 0,003). In the structural model, PEU significantly influences PU (β = 0,402, p = 0,001) and Attitude Toward Use (AT) (β = 0,270, p = 0,005), while PU strongly predicts AT (β = 0,526, p = 0,001) and Behavioral Intention (BI) (β = 0,392, p = 0,001). AT emerges as the most powerful determinant of BI (β = 0,591, p = 0,001). Overall, the model demonstrates high explanatory capacity, with BI predicted substantially (R^2 > 0,70), confirming that both cognitive (PEU, PU) and motivational (SE, PE) constructs jointly shape students' acceptance of MobGam.
Conclusions: this study extends the applicability of TAM in the context of MobGam by integrating SE and PE as key determinants of technology acceptance. Practically, the findings suggest that educators and instructional designers should emphasize PE, SE, PEU, PE, and AT when implementing MobGam systems to foster learning qulality and sustainable technology adoption in line with SDG 4.

Keywords: Quality Education; Mobile-Based Gamification Learning; Technology Acceptance Model; Perceived Enjoyment; Self-Efficacy; Engineering Education.

RESUMEN

Introducción: la transformación digital en la era de Education 4.0 ha redefinido de manera significativa la educación superior, incluida la educación en ingeniería. En consonancia con Sustainable Development Goal (SDG) 4: Quality Education, el mobile-based gamification learning (MobGam) ha surgido como un enfoque innovador para mejorar la calidad del aprendizaje. Este estudio tiene como objetivo analizar la behavioral intention (BI) de los estudiantes de adoptar MobGam mediante la ampliación del Technology Acceptance Model (TAM) con dos constructos externos: Self-Efficacy (SE) y Perceived Enjoyment (PE).
Método: se llevó a cabo una encuesta cuantitativa con 127 estudiantes de Ingeniería Eléctrica Industrial en Indonesia. Los datos se recopilaron mediante un cuestionario con escala Likert de cinco puntos y se analizaron utilizando Partial Least Squares-Structural Equation Modeling (PLS-SEM) para evaluar tanto el modelo de medida como el modelo estructural.
Resultados: los resultados muestran que PE mejora significativamente tanto Perceived Ease of Use (PEU) (β = 0,553, p = 0,001) como Perceived Usefulness (PU) (β = 0,301, p = 0,003). Asimismo, SE presenta un efecto positivo sólido sobre PEU (β = 0,424, p = 0,001) y PU (β = 0,296, p = 0,003). En el modelo estructural, PEU influye significativamente en PU (β = 0,402, p = 0,001) y en Attitude Toward Use (AT) (β = 0,270, p = 0,005), mientras que PU predice de manera sólida AT (β = 0,526, p = 0,001) y Behavioral Intention (BI) (β = 0,392, p = 0,001). AT se identifica como el determinante más potente de BI (β = 0,591, p = 0,001). En conjunto, el modelo demuestra una alta capacidad explicativa, con una predicción sustancial de BI (R^2 > 0,70), lo que confirma que los constructos cognitivos (PEU, PU) y motivacionales (SE, PE) conforman conjuntamente la aceptación de MobGam por parte de los estudiantes.
Conclusiones: este estudio amplía la aplicabilidad del TAM en el contexto de MobGam al integrar SE y PE como determinantes clave de la aceptación tecnológica. En términos prácticos, los hallazgos sugieren que los educadores y los diseñadores instruccionales deben enfatizar PE, SE, PEU, PU y AT al implementar sistemas MobGam, con el fin de promover la calidad del aprendizaje y una adopción tecnológica sostenible en consonancia con el SDG 4.

Palabras clave: Educación de Calidad; Aprendizaje Gamificado Basado en Dispositivos Móviles; Modelo de Aceptación Tecnológica; Disfrute Percibido; Autoeficacia; Educación en Ingeniería.

INTRODUCTION

The rapid advancement of digital technology has profoundly transformed learning practices in higher education, including in the field of engineering education. The transition to Education 4.0 requires both lecturers and students to adapt to more interactive, flexible, and learner-centered pedagogical approaches.[1,2] In this context, MobGam has emerged as a promising innovation to enhance student engagement, motivation, and learning effectiveness, particularly in conceptually demanding courses such as Electrical Engineering.[2,3,4]

This technological integration in learning aligns with SDG 4: Quality Education, which emphasizes the importance of inclusive, equitable, and high-quality education for all. SDG 4 specifically encourages the use of digital technologies to expand access, improve relevance, and foster lifelong learning opportunities.[5,6] Within engineering education, implementing MobGam reflects a commitment to building adaptive, collaborative, and student-centered learning environments.[4,5,7] Such innovation not only aims to improve academic outcomes but also to cultivate 21st-century competencies, including digital literacy, problem-solving, and self-directed learning, that are essential for future engineers.

Electrical Machine Courses typically require a deep conceptual understanding of working principles, characteristics, and electromagnetic interactions among machine components.[8,9] In practice, however, many students struggle to comprehend these abstract and complex concepts, which often leads to low engagement and limited participation in theoretical classes.[3,10] Consequently, there is a pressing need for a learning approach that can create an engaging environment while simultaneously facilitating conceptual understanding.

The gamification approach addresses this challenge by integrating game elements, such as points, challenges, and instant feedback, into the learning process. Through mobile-based platforms, students can engage in interactive and enjoyable learning experiences unbounded by time or location.[11,12] Empirical studies have shown that gamified learning environments can enhance students' intrinsic motivation, self-confidence, and persistence in learning activities.[13,14,15] Nevertheless, the success of gamification-based learning is largely determined by students' acceptance and BI to use such technologies.[16,17]

To explore the factors influencing students' acceptance of educational technologies, the TAM has been widely adopted as a theoretical framework.[17,18] The model posits that PEU and PU are key determinants of users' AT of technology, which subsequently affect their BI.[17,18] However, in the context of gamified learning, the traditional TAM framework does not fully capture the motivational and affective dimensions that influence learners' acceptance. Accordingly, this study extends the TAM by incorporating two additional external constructs: SE and PE. SE refers to an individual's belief in their ability to effectively use technology, which can shape perceptions of its ease of use and usefulness.[19,20,21] Meanwhile, PE reflects the degree to which students experience intrinsic pleasure from using the technology during the learning process.[22,23] These factors are expected to significantly contribute to positive perceptions and adoption of MobGam. By examining both cognitive and affective factors, this study aims to strengthen the theoretical link between pedagogical innovation and sustainable digital transformation in alignment with SDG 4. This study was conducted among students in the Industrial Electrical Engineering Study Program at Universitas Negeri Padang to analyze the determinants influencing students' BI to adopt MobGam in the Electrical Machine Course.

The findings of this study are expected to provide theoretical contributions by extending the application of the TAM to the context of MobGam in engineering education. In addition, the study offers practical implications for lecturers and instructional designers in developing gamification learning systems that are more effective, engaging, and responsive to students' needs. Furthermore, the results are anticipated to serve as a valuable reference for educators in selecting and implementing MobGam by considering the key factors that influence students' adoption of such technologies in the digital learning era.

METHOD

Research Design

This research adopted a quantitative methodology using a survey-based approach. The survey method was selected because it effectively captures the relationships between psychological constructs and latent behavioral variables by gathering respondents' perceptions at a specific point in time.[17,32] This approach was considered suitable for generating empirical insights into the determinants of students' BI to adopt MobGam, as well as for validating the proposed conceptual model through SEM analysis. Data were collected from students who had engaged with MobGam for one semester within an Electrical Engineering course. This sampling strategy ensured that participants had firsthand experience with MobGam in a relevant learning context, thereby enhancing the validity of the data used to assess students' BI toward MobGam and the contributing factors, particularly the influence of SE and PE as external factors to extend TAM. Furthermore, this design facilitated the investigation of both direct and mediated relationships among the constructs, as illustrated in the conceptual framework shown in figure 1.

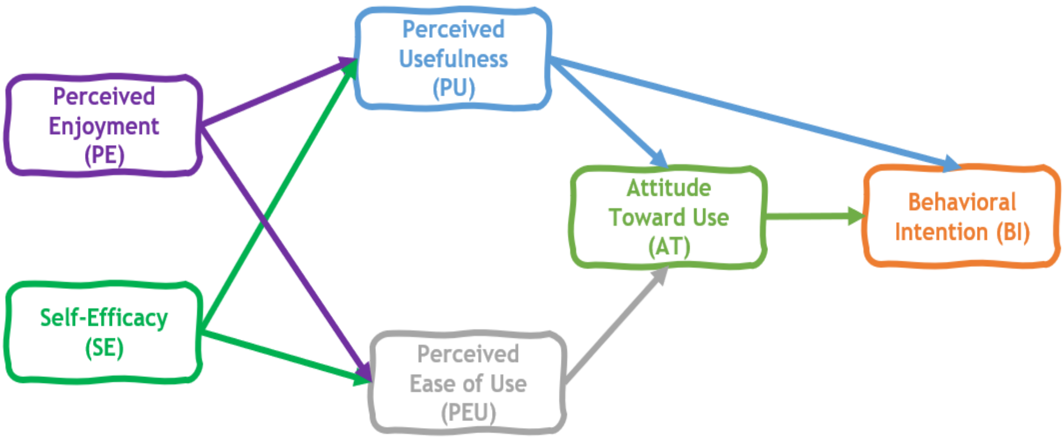

Figure 1. Research Conceptual Framework

Research Participant

The participants in this study were 127 second-year students enrolled in the Industrial Electrical Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Padang, Indonesia. The entire cohort was included because all students had completed the Electrical Machines course, in which MobGam was integrated throughout one semester. The decision to involve the full group was grounded in both methodological and substantive reasoning. From a methodological perspective, including the entire population enhances data representativeness and reduces potential selection bias that might arise from sampling only a subset of students.[16,33] From a substantive standpoint, the inclusion of all students was essential, as they shared a consistent learning experience through the MobGam intervention within the same course, thereby reinforcing the internal validity of the research.

Ethical Aspects

This study was conducted in accordance with established ethical standards for research involving human participants. Before data collection, the research protocol, instruments, and consent procedures were reviewed and approved by the Research and Community Service Institutions (LPPM) of Universitas Negeri Padang (No. 2047/UN35.15/LT/2025). All participants were informed about the purpose of the study, their voluntary participation, the confidentiality of their responses, and their right to withdraw at any time without penalty.

Informed consent was obtained from all participants before completing the questionnaire. No personally identifiable information was collected, and all data were anonymized and used solely for academic and research purposes. The study ensured full compliance with the principles of the Declaration of Helsinki and adhered to institutional data protection policies.

Research Instrument

The research employed a structured questionnaire as the primary data collection instrument, utilizing a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire items were adapted from established theoretical frameworks and prior empirical studies relevant to the investigated constructs, namely SE, PE, PEU, PU, AT, and BI. Each construct was operationalized through multiple indicators to capture its conceptual dimensions comprehensively. A detailed overview of the variables, their corresponding indicators, and the sources informing their development is provided in table 1.

Table 1. Research Instrument

Variable	Indicators
PE	PE1. Using MobGam provides an enjoyable learning experience. PE2. Using MobGam makes learning activities more entertaining. PE3. Using MobGam during the learning process enhances enthusiasm for learning. PE4. Using MobGam creates an engaging and interactive learning environment. PE5. Using MobGam fosters a sense of comfort throughout the learning process.[22,23,26]
SE	SE1. Confidence in quickly understanding the key features of MobGam. SE2. Confidence in easily learning how to operate MobGam. SE3. Confidence in mastering the use of MobGam to support learning in Electrical Machines. SE4. Confidence in using MobGam independently.[20,21,26]
PEU	PU1. MobGam is easy to use for learning activities. PU2. The features of MobGam are easy to understand and access. PU3. MobGam has a simple and user-friendly interface. PU4. The learning process through MobGam is efficient and straightforward.[16,17,18]
PU	PU1. MobGam helps students understand key concepts in Electrical Engineering learning. PU2. Using MobGam enhances the effectiveness of learning activities. PU3. MobGam accelerates students' understanding of learning materials. PU4. MobGam supports the achievement of learning objectives more efficiently. PU5. MobGam contributes to improving the overall quality of learning.[16,17,18,30]
AT	AT1. Using MobGam represents a positive approach to learning. AT2. Implementing MobGam is an effective idea for enhancing learning activities. AT3. MobGam serves as an engaging method to support students' understanding of the material. AT4. MobGam fosters positive perceptions toward the use of technology in education.[16,29,30]
BI	BI1. Continued use of MobGam is planned for future learning activities. BI2. MobGam will be used again if available in other courses. BI3. The use of MobGam is recommended to fellow students. BI4. Continuous use of MobGam is expected to support independent learning. BI5. Sustainable implementation of MobGam is intended for future learning practices.[16,17,18,30]

The research instrument underwent a comprehensive validation process to ensure that each item accurately measured the intended constructs. Content validity was first evaluated by a panel of eight experts, comprising four lecturers in electrical engineering education, two in learning technology, and two practitioners specializing in digital learning. These experts assessed the relevance of each indicator to its corresponding construct, the clarity of the wording, and the contextual suitability within engineering education. Based on their input, several items were refined to improve linguistic clarity and eliminate potential ambiguities.

Following expert validation, a pilot study was conducted with 33 students who were not part of the main research sample but possessed similar characteristics to the target respondents. The pilot data were analyzed to evaluate both the validity and reliability of the instrument quantitatively. Item validity was tested using the Pearson Product-Moment correlation between each item and its total construct score.[16,34] The resulting correlation coefficients ranged from 0,59 to 0,73 ($p < 0,01$), confirming that all items met the validity criterion. Reliability analysis using Cronbach's alpha yielded values between 0,79 and 0,86 across all constructs, surpassing the recommended minimum threshold of 0,70[16,17], thus affirming the instrument's internal consistency.

Data Analysis Technique

The research data were analyzed using the PLS-SEM technique implemented in SmartPLS version 4.0. This method was chosen because it aligns with the study's objective of examining causal relationships among latent constructs, including both direct and mediated effects.[16,35] PLS-SEM is particularly suitable for predictive and exploratory research involving relatively small to medium sample sizes.[35,36,37] Given the sample of 127 respondents and a model comprising six latent constructs with mediating relationships, this analytical approach was considered appropriate for the present study.

The PLS-SEM analysis was carried out in three sequential phases. First, model assumptions and model fit were assessed to verify that the dataset met the fundamental analytical requirements. Multicollinearity was examined using the Variance Inflation Factor (VIF), while model fit was evaluated through the Standardized Root Mean Square Residual (SRMR), Normed Fit Index (NFI), and Chi-Square statistics.[35,38] Second, the outer model was tested to establish construct validity and reliability. Convergent validity was determined based on outer loadings (OL), Average Variance Extracted (AVE $\geq$ 0,50), and Composite Reliability (CR $\geq$ 0,70). In contrast, discriminant validity (DV) was assessed using the Heterotrait-Monotrait Ratio of Correlations (HTMT).[17,35] Construct reliability was further verified through Cronbach's alpha (CA), ensuring internal consistency across measurement indicators. Finally, the inner model was analyzed to evaluate the structural relationships among latent variables, encompassing direct, indirect (mediated), and total effects. The overall explanatory power of the model was determined using the coefficient of determination (R^2), and the statistical significance of the path coefficients was assessed via bootstrapping to obtain p-values.[16,17,35]

RESULTS

Mobile-Based Gamification Learning

The advancement of mobile technology has created new opportunities for the digital transformation of learning, one of which is the MobGam approach. This approach integrates core gamification principles such as points, badges, rankings, challenges, and real-time feedback into a learning environment accessible via mobile devices.[13,16,24] The objective is not merely to introduce games into education, but to leverage game mechanics to enhance students' motivation, participation, and engagement in the learning process.[24,25] Within the context of engineering education, MobGam has proven to be effective in fostering active and engaging learning experiences, particularly for conceptual subjects such as Electrical Engineering, where students often encounter difficulties in understanding abstract theories.[1,2,20] Through its high degree of interactivity and flexibility in terms of time and space, MobGam promotes a stronger sense of ownership in learning, facilitates self-directed learning, and improves retention of technical concepts more effectively than conventional approaches.[1,4]

In this study, MobGam was developed using Gimkit, a platform tool designed to transform conventional learning activities into interactive and collaborative competitions. Gimkit enables instructors to design quizzes and learning sessions that integrate elements of speed, strategy, and point accumulation, thereby encouraging students to think critically, engage in healthy competition, and remain focused on learning content. Compared to other gamification platforms, Gimkit offers a distinctive feature in the form of an in-game currency system that rewards students for their performance and allows them to "upgrade" their abilities in subsequent sessions. This mechanism enhances replay value and fosters intrinsic motivation, as students perceive the learning process as not only enjoyable but also continuously challenging. The implementation of MobGam used in this study is illustrated in figure 2.

https://doi.org/10.56294/saludcyt20262605 ISSN: 2796-9711

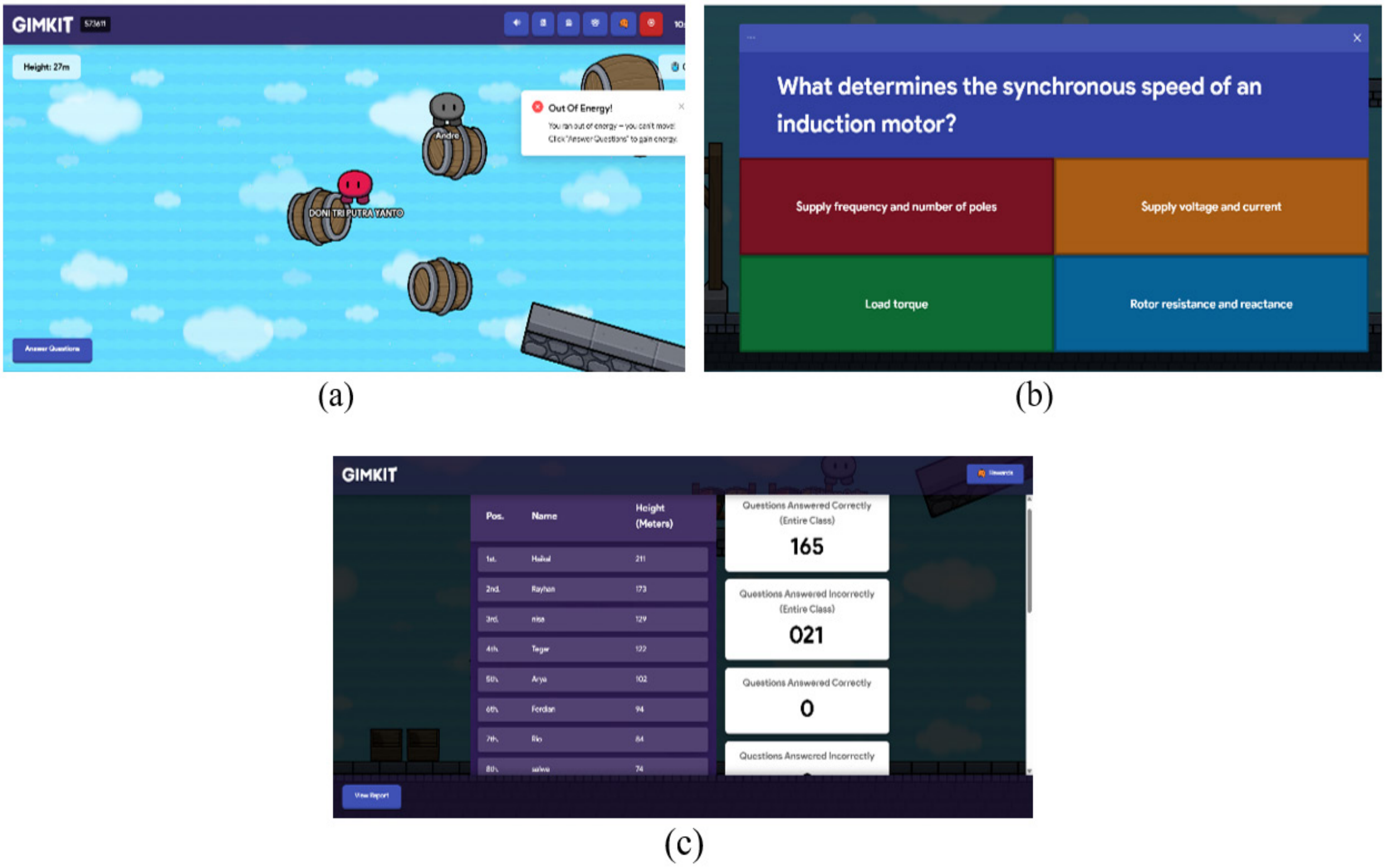

Figure 2. MobGam display using Gimkit: (a) students compete to reach the highest level by answering questions to earn energy, (b) sample questions are presented for students to answer, and (c) a live scoreboard display

The initial Research Conceptual Framework, illustrated in figure 1, was assessed to ensure adherence to fundamental assumptions and analytical requirements. This assessment focused on evaluating the constructs and their associated indicators to confirm the validity of the measurement model, verify the absence of statistical issues such as multicollinearity, and ensure conformity with model fit criteria. The results, summarized in table 2, revealed that all constructs had VIF values substantially below the recommended threshold of 5, confirming the absence of multicollinearity among both endogenous and exogenous variables.[35,36] In addition to the construct-level analysis, multicollinearity was also examined at the indicator level. As presented in table 3, all indicators exhibited VIF values below the recommended threshold, signifying that the model was not affected by multicollinearity. Following this, the subsequent analytical step involved assessing the overall model fit to ensure the model adequately represented the observed data.

Table 2. The results of the Inner VIF Analysis

	PEU	PU	AT	BI
PE	0,730	1,650	-	-
SE	0,711	0,801	-	-
PEU	-	0,799	0,709	-
PU	-	-	0,815	0,794
AT	-	-	-	0,922

The model fit analysis revealed that the NFI values for the saturated and estimated models (1,015 and 1,003, respectively) exceeded the acceptable threshold of 0,90, while the SRMR values (0,080 and 0,083) were below 0,08, and the RMS Theta values (0,081 and 0,085) were below 0,102. Collectively, these indices demonstrate that the model achieved a satisfactory level of Model Fit.[32,35] Compliance with these fit criteria confirms the structural adequacy and overall robustness of the model, ensuring its suitability for subsequent hypothesis testing. The final structural model, along with the estimated path coefficients and interrelationships among indicators, is depicted in figure 3, which presents the results of the final analysis.

https://doi.org/10.56294/saludcyt20262605 ISSN: 2796-9711

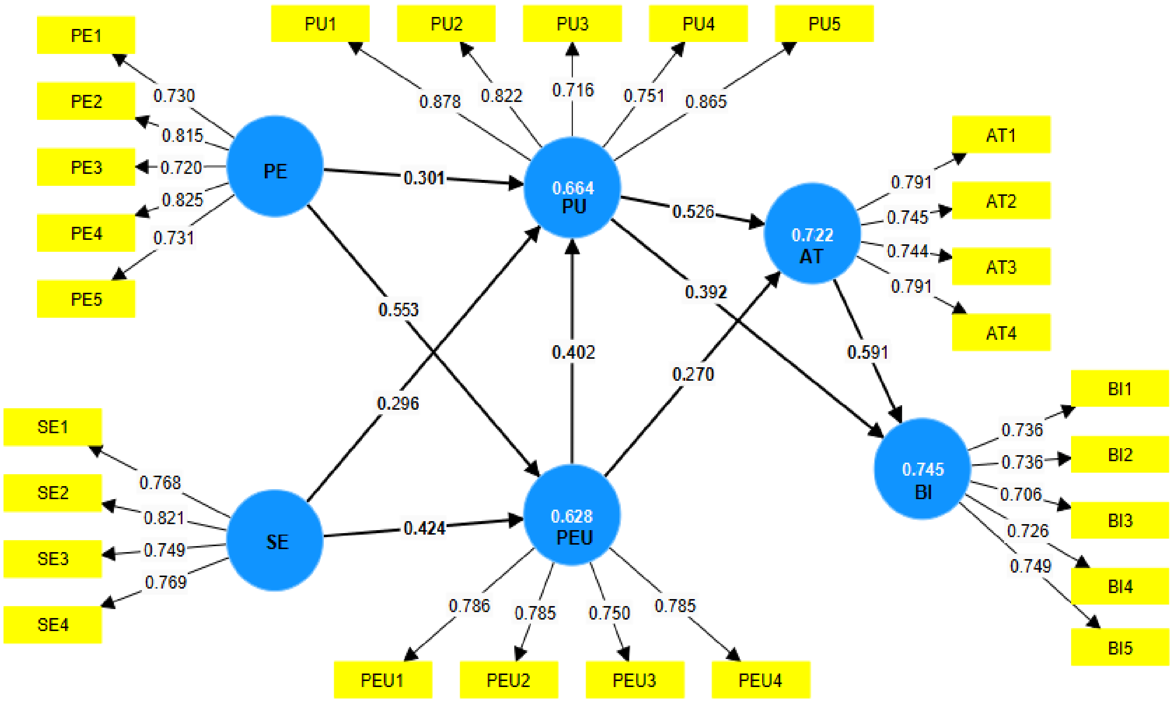

Figure 3. The Visualization of the final analysis result using PLS-SEM

Indicator Analysis

The indicator (outer model) analysis focuses on evaluating the measurement model to ensure that the observed indicators accurately and consistently represent their respective latent constructs. Internal Consistency Reliability (ICR) was assessed to determine the degree to which indicators consistently measure the intended construct, as reflected by CA values. As shown in table 3, all constructs recorded CA values above 0,70, confirming that the indicators demonstrated acceptable reliability.(16,17,35) The unidimensionality assessment further verified that the measurement model was free from structural inconsistencies. The results presented in table 3 indicate that all constructs fulfilled the unidimensionality requirement, with both CR and CA values exceeding the 0,70 benchmark.(16,39) Moreover, CV was evaluated to ensure that indicators within each construct were sufficiently correlated. The analysis revealed that all constructs met the CV criterion, as indicated by AVE values greater than 0,50 for all variables.(35,39)

Table 3. The results of the VIF and indicators analysis

	Outer VIF	OL	CR	CA	rho_A	AVE
PE			0,876	0,822	0,828	0,586
PE.1	1,555	0,730	-	-	-	-
PE.2	1,914	0,815				
PE.3	1,581	0,720				
PE.4	1,905	0,825				
PE.5	1,482	0,731				
SE			0,859	0,781	0,787	0,604
SE.1	1,550	0,768	-	-	-	-
SE.2	1,663	0,821				
SE.3	1,468	0,749				
SE.4	1,468	0,769				
PEU			0,818	0,702	0,703	0,530
PEU.1	1,287	0,786	-	-	-	-
PEU.2	1,220	0,785				
PEU.3	1,596	0,750				
PEU.4	1,703	0,850				

PU			0,849	0,777	0,781	0,531
PU.1	1,407	0,878	-	-	-	-
PU.2	1,916	0,822				
PU.3	1,478	0,716				
PU.4	1,513	0,751				
PU.5	1,336	0,865				
AT			0,810	0,787	0,787	0,516
AT.1	1,288	0,791	-	-	-	-
AT.2	1,385	0,745				
AT.3	1,359	0,744				
AT.4	1,204	0,791				
BI			0,851	0,782	0782	0,534
BI.1	1,703	0,736	-	-	-	-
BI.2	1,536	0,736				
BI.3	1,575	0,706				
BI.4	1,544	0,726				
BI.5	1,623	0,749				

DV in this study was examined using the HTMT. This approach is recognized as a more sensitive and precise method compared to traditional techniques, such as the Fornell–Larcker criterion, for identifying potential DV issues.[35,38] The HTMT assesses the degree to which constructs are empirically distinct by comparing the average correlations between indicators of different constructs (heterotrait–heteromethod) with those among indicators of the same construct (monotrait–heteromethod). As shown in table 4, all HTMT values for the construct pairs were below the recommended cutoff value of 0,85, indicating that each construct exhibited sufficient DV and captured a unique conceptual domain.[16,38] Consequently, the measurement model in this study satisfied the criteria for adequate DV, confirming the absence of construct overlap that could potentially confound the interpretation of the findings.

Table 4. The results of the HTMT Analysis

	PE	SE	PEU	PU	AT
SE	0,572	-	-	-	-
PEU	0,693	0,666	-	-	-
PU	0,571	0,541	0,693	-	-
AT	0,586	0,637	0,711	0,713	
BI	0,506	0,557	0,712	0,630	0,716

Constructs Analysis

This analysis examined the direct, indirect, total, and simultaneous effects among the variables. The strength and direction of these effects (direct, indirect, and total) were represented by path coefficients, which range from –1 to +1. A coefficient value approaching +1 indicates a strong positive relationship, whereas a value approaching 1 reflects a strong negative relationship.[16,35] As shown in table 5, PE demonstrated a positive and significant effect on PEU (β = 0,553, p < 0,05) and PU (β = 0,301, p < 0,05). This suggests that the level of enjoyment students experience while using MobGam enhances their perceptions of both the ease and usefulness of the learning system. Similarly, SE exhibited a significant positive effect on PEU (β = 0,424, p < 0,05) and PU (β = 0,296, p < 0,05), indicating that students' confidence in operating digital learning applications substantially influences their perceptions of ease and usefulness.

Moreover, PEU was found to have a significant positive effect on PU (β = 0,402, p < 0,05) and AT (β = 0,270, p < 0,05), reaffirming the core premise of TAM that technologies perceived as easy to use are more likely to be viewed as beneficial and to foster positive user attitudes. In addition, PU significantly affected both AT (β = 0,526, p < 0,05) and BI (β = 0,392, p < 0,05), implying that students who perceive tangible learning benefits and increased motivation from MobGam develop favorable attitudes and stronger intentions to continue its use. Finally, AT exerted the strongest influence on BI (β = 0,591, p < 0,05), underscoring that students' positive attitudes are the primary determinant of their behavioral intentions to adopt gamification-based learning in the future. Overall, these findings confirm that the proposed model effectively explains students' acceptance of MobGam. The variables PE, SE, PEU, and PU collectively contribute to shaping students' AT and BI toward using MobGam as an interactive, engaging, and effective learning medium in the context of engineering education.

Table 5. Direct effects in the constructs analysis

No.	Direct Effect	β	P-value
1	PE → PEU	0,553	0,001
2	PE → PU	0,301	0,003
3	SE → PEU	0,424	0,001
4	SE → PU	0,296	0,003
5	PEU → PU	0,402	0,001
6	PEU → AT	0,270	0,005
7	PU→ AT	0,526	0,001
8	PU → BI	0,392	0,001
9	AT → BI	0,591	0,001

The indirect effect analysis was conducted to determine the extent to which exogenous variables influence endogenous variables through intervening variables. In other words, this analysis examined the mediating roles of specific constructs in transmitting the effects of exogenous factors on endogenous outcomes. As presented in table 6, the findings reveal that PE has a positive and statistically significant indirect effect on PU, mediated by PEU. Furthermore, the indirect impact of PE on AT (mediated by PEU and PU) and on BI (mediated by PU) was also positive and significant.

Similarly, SE, as another external construct, was found to exert a positive and statistically significant indirect effect on PU (through PEU mediation), AT (through PEU and PU mediation), and BI (through PU mediation). These findings reinforce the conclusion that both PE and SE effectively extend the original TAM framework by acting as critical antecedent factors influencing students' adoption of MobGam in the learning process. Overall, the indirect effect analysis confirms that all mediating pathways in this study are positive and significant, indicating that the intervening variables play a substantial role in transmitting the influence of exogenous constructs on endogenous outcomes.

Table 6. Indirect effects in the constructs analysis

No.	Indirect Effect	β	P-value
1	PE → PEU→ PU	0,222	0,008
2	PE → PEU→ AT	0,150	0,009
3	PE → PU→ AT	0,158	0,009
4	PE → PU→ BI	0,118	0,014
5	SE → PEU→ PU	0,171	0,009
6	SE → PEU→ AT	0,115	0,014
7	SE → PU→ AT	0,157	0,009
8	SE → PU→ BI	0,116	0,014
9	PEU → PU→ AT	0,212	0,008
10	PEU → PU→ BI	0,158	0,009
11	PEU → AT→ BI	0,160	0,009
12	PU → AT→ BI	0,311	0,003

The role of indirect effects can also be understood through the total effects, which represent the cumulative impact of both direct and indirect influences of each exogenous variable on its corresponding endogenous variable. A positive indirect effect strengthens the total effect, thereby surpassing the magnitude of the direct impact alone. As shown in table 7, all indirect pathways contribute to reinforcing the direct effects in the model, as evidenced by the higher β values of the total effects compared to their respective direct effects. All total effects were positive and statistically significant ($p < 0,05$), indicating that each exogenous construct exerts a meaningful overall influence on the endogenous variables.

In addition, the simultaneous effects were assessed using the coefficient of determination (R^2) and the adjusted R^2, with thresholds classified as weak (R^2 = 0,19), moderate (R^2 = 0,33), and substantial (R^2 = 0,67).[16,35,36] The analysis results indicate that the simultaneous influence of PE and SE on PEU is moderate (Adj. R^2 = 0,623). The combined influence of PE, SE, and PEU on PU is also moderate (Adj. R^2 = 0,659). Meanwhile, the simultaneous influence of PE, SE, PEU, and PU on AT is substantial (Adj. R^2 = 0,719), as is the combined effect of PE, SE, PEU, PU, and AT on BI (Adj. R^2 = 0,740). These findings suggest that the proposed model has strong explanatory power in predicting students' acceptance and BI toward MobGam in engineering education contexts.

Table 7. Total effects in the constructs analysis

No.	Total Effect	β	P-value
2	PE → PU	0,523	0,001
4	SE → PU	0,467	0,001
6	PEU → AT	0,482	0,001
7	PU→ AT	0,526	0,001
8	PU → BI	0,703	0,001

DISCUSSION

The results of this study demonstrate that the developed MobGam-TAM model effectively and comprehensively explains the factors influencing students' acceptance of MobGam in the Electrical Machine Course. All relationships among the variables exhibit a consistent positive direction, thereby reinforcing the theoretical validity of the adapted model. These findings not only reaffirm the robustness of the original TAM but also extend it through the integration of two key external constructs, PE and SE. Both factors significantly contribute to shaping students' PEU, PU, AT, and BI in adopting MobGam as an innovative digital learning strategy.

PE emerged as a dominant factor that bridges the emotional and cognitive dimensions in the technology acceptance process. Students' enjoyment while using MobGam was found to enhance their perceptions of the system's ease of use and usefulness. This finding is plausible, as enjoyable learning experiences encourage students to remain focused and actively engaged, thereby reducing perceptions of technical difficulty and increasing the perceived benefits of the system. These results are consistent with prior studies that identified intrinsic enjoyment as one of the strongest predictors of positive perceptions toward game-based learning technologies.[17,22,23] In the context of Electrical Engineering, where the material is often abstract and theoretically complex, MobGam creates a more dynamic and interactive learning environment, enabling students to grasp technical concepts through more concrete, engaging, and practice-oriented experiences.

Moreover, the role of PE extends beyond shaping initial perceptions, exerting indirect effects on students' AT and BI through the mediation of PEU and PU. This suggests that the enjoyment experienced during the use of MobGam not only provides immediate emotional satisfaction but also fosters positive beliefs about the system's functionality and efficiency. When students perceive learning as both enjoyable and meaningful, they are more likely to develop positive attitudes and a sustained intention to continue using the technology. These findings support assertions that enjoyable experiences in technological interaction play a crucial role in reinforcing users' adoption intentions, particularly in the context of digital learning.[16,22,26]

In addition to affective factors, SE is a key cognitive determinant that significantly influences the acceptance of learning technologies. Students with higher levels of confidence in their ability to operate technology tend to perceive MobGam as easier to use and more beneficial for achieving learning outcomes. These findings are in line with previous studies that confirmed user confidence as a critical determinant of both perceived ease of use and perceived usefulness in technology adoption.[20,21,26] In the field of engineering education, where learning often involves interaction with abstract concepts and complex technological systems, SE plays an essential role in reducing technical barriers and improving learning efficiency.[20,30] Hence, the higher a student's confidence level, the more likely they are to view gamification technology as a tool that effectively supports the achievement of learning goals.

The influence of SE in this study also manifests indirectly, contributing to the formation of AT and BI through PEU and PU. Students who feel confident in using MobGam not only perceive the system as easier to operate but also recognize its added value in enhancing their understanding of the learning material. This confidence fosters a greater sense of control over their digital learning experience, which naturally cultivates a positive attitude toward technology adoption. These findings are consistent with prior studies emphasizing that SE not only affects technical capability but also reinforces perceptions of the value and usefulness of educational technologies.[20,29,30]

The results of this study also reaffirm the relevance of the core relationships proposed in the classic TAM.

PEU was found to positively influence both PU and AT. This finding indicates that the easier a system is to operate, the more beneficial it is perceived to be, and the more positive students' attitudes become toward its use. In the context of MobGam, features such as an intuitive interface, simple navigation, and seamless accessibility via mobile devices enable students to interact comfortably and confidently with the system. This result is consistent with prior research confirming that ease of use is a critical factor in shaping both perceived usefulness and attitudes toward technology.[16,17,29] In other words, ease of use serves as a foundational prerequisite for developing positive attitudes toward digital learning technologies.

PU also plays a pivotal role in shaping students' positive AT and BI. When students perceive that using MobGam helps them better understand complex concepts, accelerates their learning process, and improves their academic performance, they tend to exhibit more favorable and enthusiastic attitudes toward its continued use. This finding reinforces the argument of earlier studies emphasizing that PU is a key driver of technology adoption intentions, as users are more inclined to continue using technologies that demonstrably enhance their learning performance and efficiency.[29,30,32] In the context of engineering education, where learning content is often abstract and conceptually demanding, the tangible benefits students experience, such as improved comprehension and motivation, encourage them to adopt gamification as an integral component of contemporary learning strategies.

AT emerged as the most influential psychological factor affecting BI. Students with positive attitudes toward MobGam exhibited a strong tendency to continue using it in future learning contexts. Such attitudes are shaped by the combined influence of PEU, PU, PE, and SE. From a learning psychology perspective, a positive AT signifies successful internalization of technology, where users perceive the system not only as functional but also as relevant to their personal learning goals and styles. This result aligns with previous studies highlighting that AT serves as a critical mediator linking perception to BI in educational technology adoption.[16,17,32] In the context of MobGam, a positive attitude strengthens students' willingness to sustain their engagement with gamified learning, both individually and collaboratively.

BI, the terminal construct in the model, reflects students' inclination to continue using MobGam as part of their learning activities. This intention signifies a strong acceptance of the gamification-based learning approach, influenced by a combination of cognitive factors (SE, PU, PEU) and affective factors (PE, AT). Students who perceived the system as easy to use, useful, enjoyable, and aligned with their learning needs demonstrated higher intentions to continue using it in the future. This finding supports prior theoretical and empirical evidence indicating that BI serves as a key predictor of technology continuance.[16,17,33] Within the context of engineering education, this outcome signifies the successful integration of digital learning innovations, where sustained use represents a critical prerequisite for the long-term effectiveness and institutionalization of gamification-based instructional strategies.

Conceptually, the findings of this study provide a significant contribution to strengthening and expanding the TAM within the context of engineering education. The extended TAM model simultaneously integrates both cognitive and affective dimensions, demonstrating that technology acceptance is influenced not only by rational evaluations but also by users' emotional experiences and SE. Theoretically, these findings support the argument that extending TAM by incorporating motivational and affective factors enhances its predictive capability in explaining technology acceptance within digital learning environments.[14,15,33]

From a practical perspective, this study offers valuable guidance for educators and instructional designers in developing gamification strategies that emphasize not only usability and perceived usefulness but also the creation of enjoyable learning experiences and the reinforcement of students' technological self-confidence. The results underscore the need for a more human-centered approach in choosing and designing digital learning systems that integrate psychological engagement with technological functionality to optimize learning effectiveness.

Overall, this study confirms that the successful implementation of MobGam depends not solely on the technical quality of the system but also on the psychological dynamics of its users. PE and SE have been identified as two critical pillars that shape students' perceptions, attitudes, and behavioral intentions toward the use of learning technologies. When students feel confident, experience enjoyment, and perceive the system as both easy to use and useful, technology adoption transitions from a temporary novelty to a sustainable learning habit. This represents the core contribution of the MobGam-TAM model, which not only strengthens the theoretical foundation of technology acceptance but also offers a contextually relevant framework for developing effective, humanistic, and adaptive digital learning strategies in the era of Education 4.0.

Limitations and Future Works

Despite its significant contributions, this study has several limitations. First, it was conducted within the context of an Electrical Machines course in a single Industrial Electrical Engineering study program, which may limit the generalizability of the findings to other disciplines or educational settings. Nevertheless, this contextual focus provides exploratory depth by revealing the dynamics of technology acceptance in the specific and complex context of engineering education. Second, the study employed a quantitative design based primarily on students' self-reported perceptions. Although statistically reliable, this approach may not fully capture the richness of students' affective and behavioral experiences during the actual use of MobGam. Therefore, future research is recommended to adopt mixed-method or qualitative approaches to gain a more holistic understanding of user experiences. Future studies could focus on testing and validating the MobGam-TAM model across different engineering or vocational disciplines, encompassing both practical and theoretical learning contexts. Further research may also explore additional external factors to enrich the understanding of how cognitive, affective, and contextual variables interact in shaping technology acceptance. Moreover, cross-institutional and cross-cultural comparative studies are encouraged to examine the consistency and generalizability of the model across broader educational contexts, thereby contributing to a more comprehensive understanding of gamification-based learning adoption in the era of Education 4.0.

CONCLUSIONS

This study confirms that the developed MobGam-TAM model effectively explains the factors influencing students' acceptance of MobGam in Electrical Machines Courses. The findings indicate that technology acceptance is shaped not only by cognitive factors but also by affective dimensions arising from enjoyable learning experiences and users' confidence in using technology. Two external constructs, PE and SE, were found to play a significant role in strengthening the core relationships within the TAM framework, encompassing PEU, PU, AT, and BI. From a theoretical perspective, this study contributes to the expansion of TAM by integrating emotional and psychological dimensions into the educational technology acceptance model. The findings support the notion that the adoption of learning technologies cannot be fully explained through users' rational perceptions alone but must also account for affective experiences and SE beliefs. From a practical standpoint, the results provide valuable insights for educators in choosing and designing gamification-based learning strategies that emphasize not only technological ease and functionality but also the creation of enjoyable learning environments, the cultivation of intrinsic motivation, and the enhancement of students' confidence in interacting with learning technologies. Such approaches are expected to increase active participation, strengthen cognitive engagement, and promote the sustained use of learning technologies in the future.

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FUNDING
None.

CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION
Conceptualization: Habibullah, Doni Tri Putra Yanto, Oriza Candra, Agariadne Dwinggo Samala.
Data curation: Habibullah, Doni Tri Putra Yanto, Refi Revina.
Formal analysis: Doni Tri Putra Yanto, Oriza Candra.
Research: Habibullah, Oriza Candra, Refi Revina, Agariadne Dwinggo Samala.
Methodology: Habibullah, Oriza Candra, Soha Rawas, Juan Luis Cabanillas-García.
Project management: Doni Tri Putra Yanto.
Resources: Habibullah, Oriza Candra, Refi Revina, Juana Maria Arcelus-Ulibarrena.
Software: Habibullah, Doni Tri Putra Yanto.
Supervision: Habibullah, Doni Tri Putra Yanto, Oriza Candra.
Validation: Habibullah, Oriza Candra, Agariadne Dwinggo Samala.
Display: Habibullah, Refi Revina, Soha Rawas.
Drafting - original draft: Habibullah, Doni Tri Putra Yanto, Oriza Candra, Refi Revina.
Writing - proofreading and editing: Doni Tri Putra Yanto, Soha Rawas, Juan Luis Cabanillas-García, Juana Maria Arcelus-Ulibarrena.