BUKTI KORESPONDENSI

ARTIKEL JURNAL NASIONAL BEREPUTASI

Judul artikel	:	Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement
Jurnal	:	*Southeast Asian Mathematics Education Journal SEAMEJ* SINTA 2 Electronic ISSN: 2721-8546 Print ISSN: 2089-4716
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Penulis	:	Dwi Yulianto, Egi Adha Juniawan, Syahrul Anwar, Yusup Junaedi

No.	Perihal	Tanggal	Lampiran Dokumen
1	Bukti konfirmasi submit artikel beserta artikel yang disubmit	8 April 2025	
2	Bukti konfirmasi review beserta hasil review pertama	21 Mei 2025	Lampiran 1
3	Bukti konfirmasi submit revisi pertama, respons kepada reviewer, beserta artikel hasil revisi yang disubmit kembali	11 Juni 2025	Lampiran 2
4	Bukti konfirmasi review beserta hasil review kedua	21 Mei 2025	Menulis di email
5	Bukti konfirmasi submit revisi kedua, respons kepada reviewer, beserta artikel hasil revisi yang disubmit kembali	11 Juni 2025	
6	Bukti konfirmasi artikel diterima (*accepted*)	7 Juli 2025	
7	Bukti konfirmasi artikel dipublikasikan secara daring (*published online*)	7 Juli 2025	
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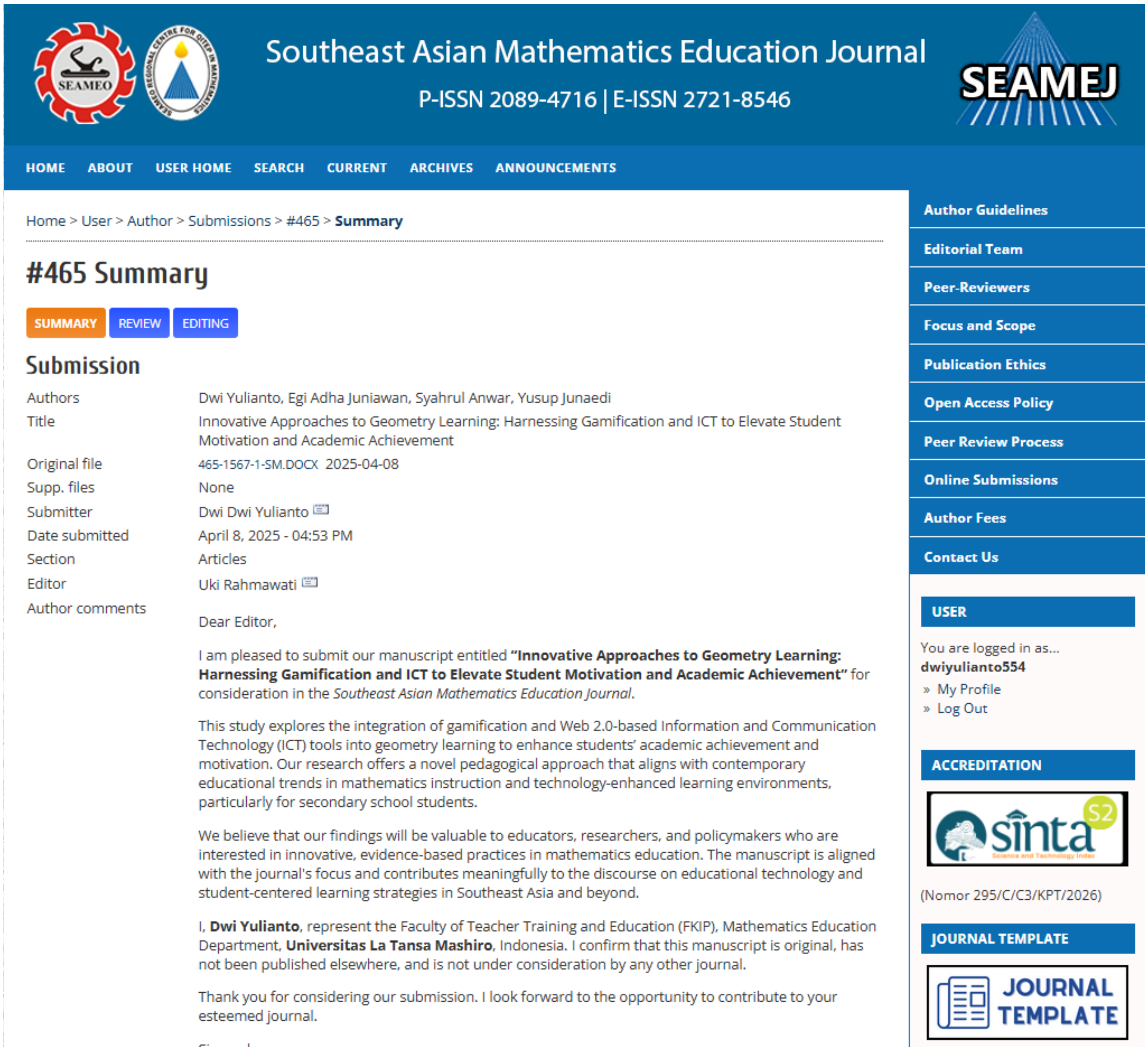

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#465 Summary

SUMMARY REVIEW EDITING

Submission

Authors	Dwi Yulianto, Egi Adha Juniawan, Syahrul Anwar, Yusup Junaedi
Title	Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement
Original file	465-1567-1-SM.DOCX 2025-04-08
Supp. files	None
Submitter	Dwi Dwi Yulianto
Date submitted	April 8, 2025 - 04:53 PM
Section	Articles
Editor	Uki Rahmawati
Author comments	Dear Editor,

I am pleased to submit our manuscript entitled **"Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement"** for consideration in the *Southeast Asian Mathematics Education Journal*.

This study explores the integration of gamification and Web 2.0-based Information and Communication Technology (ICT) tools into geometry learning to enhance students' academic achievement and motivation. Our research offers a novel pedagogical approach that aligns with contemporary educational trends in mathematics instruction and technology-enhanced learning environments, particularly for secondary school students.

We believe that our findings will be valuable to educators, researchers, and policymakers who are interested in innovative, evidence-based practices in mathematics education. The manuscript is aligned with the journal's focus and contributes meaningfully to the discourse on educational technology and student-centered learning strategies in Southeast Asia and beyond.

I, **Dwi Yulianto**, represent the Faculty of Teacher Training and Education (FKIP), Mathematics Education Department, **Universitas La Tansa Mashiro**, Indonesia. I confirm that this manuscript is original, has not been published elsewhere, and is not under consideration by any other journal.

Thank you for considering our submission. I look forward to the opportunity to contribute to your esteemed journal.

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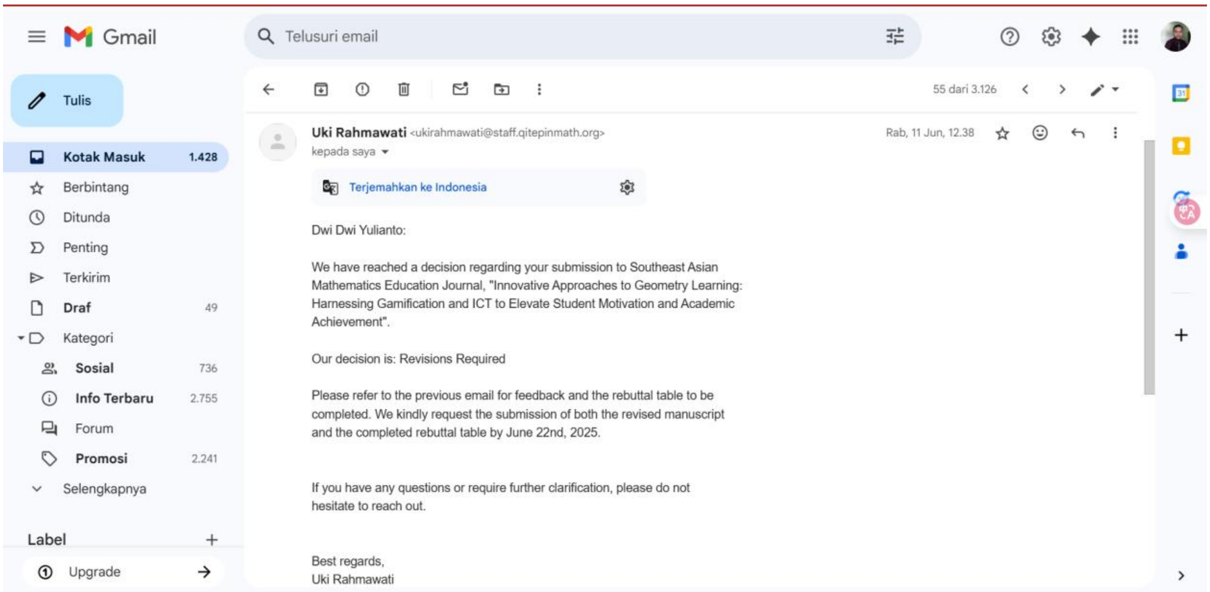

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55 dari 3.126

Uki Rahmawati <ukirahmawati@staff.qitepinmath.org> Rab, 11 Jun, 12.38
kepada saya
Terjemahkan ke Indonesia

Dwi Dwi Yulianto:

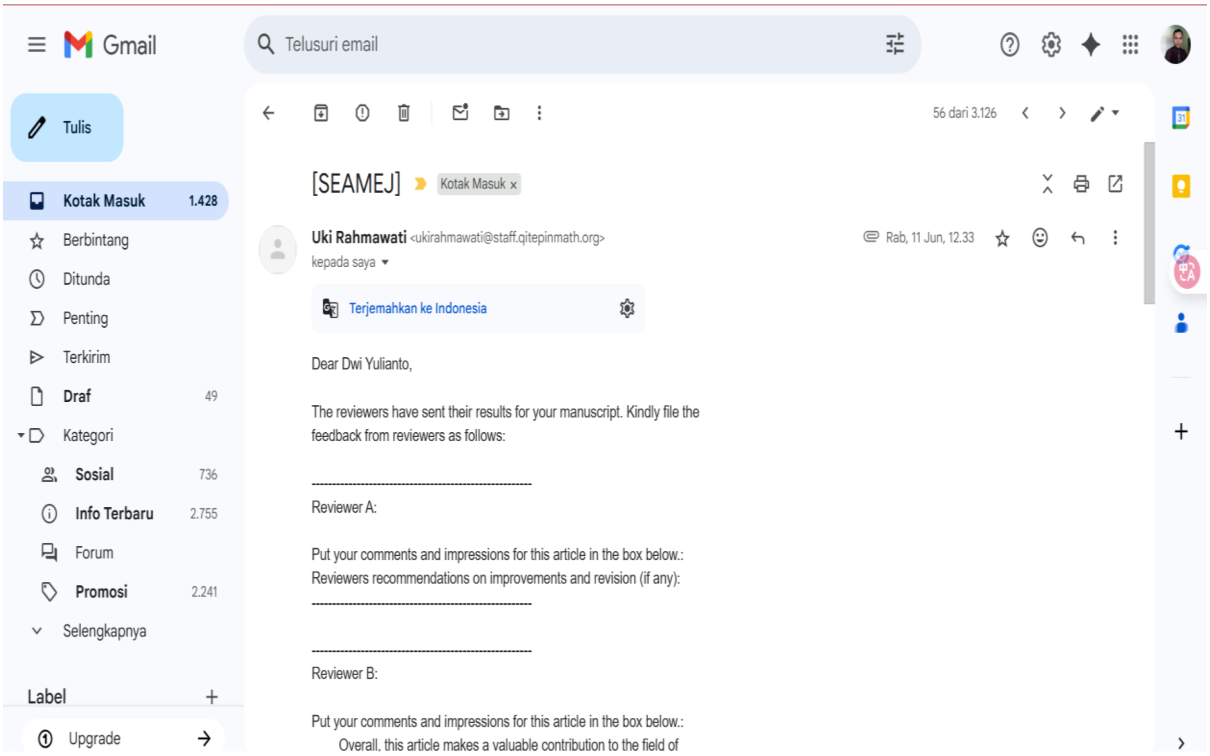
We have reached a decision regarding your submission to Southeast Asian Mathematics Education Journal, "Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement".

Our decision is: Revisions Required

Please refer to the previous email for feedback and the rebuttal table to be completed. We kindly request the submission of both the revised manuscript and the completed rebuttal table by June 22nd, 2025.

If you have any questions or require further clarification, please do not hesitate to reach out.

Best regards,
Uki Rahmawati



[SEAMEJ] Kotak Masuk

Uki Rahmawati <ukirahmawati@staff.qitepinmath.org> Rab, 11 Jun, 12.33

kepada saya

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Dear Dwi Yulianto,

The reviewers have sent their results for your manuscript. Kindly file the feedback from reviewers as follows:

Reviewer A:

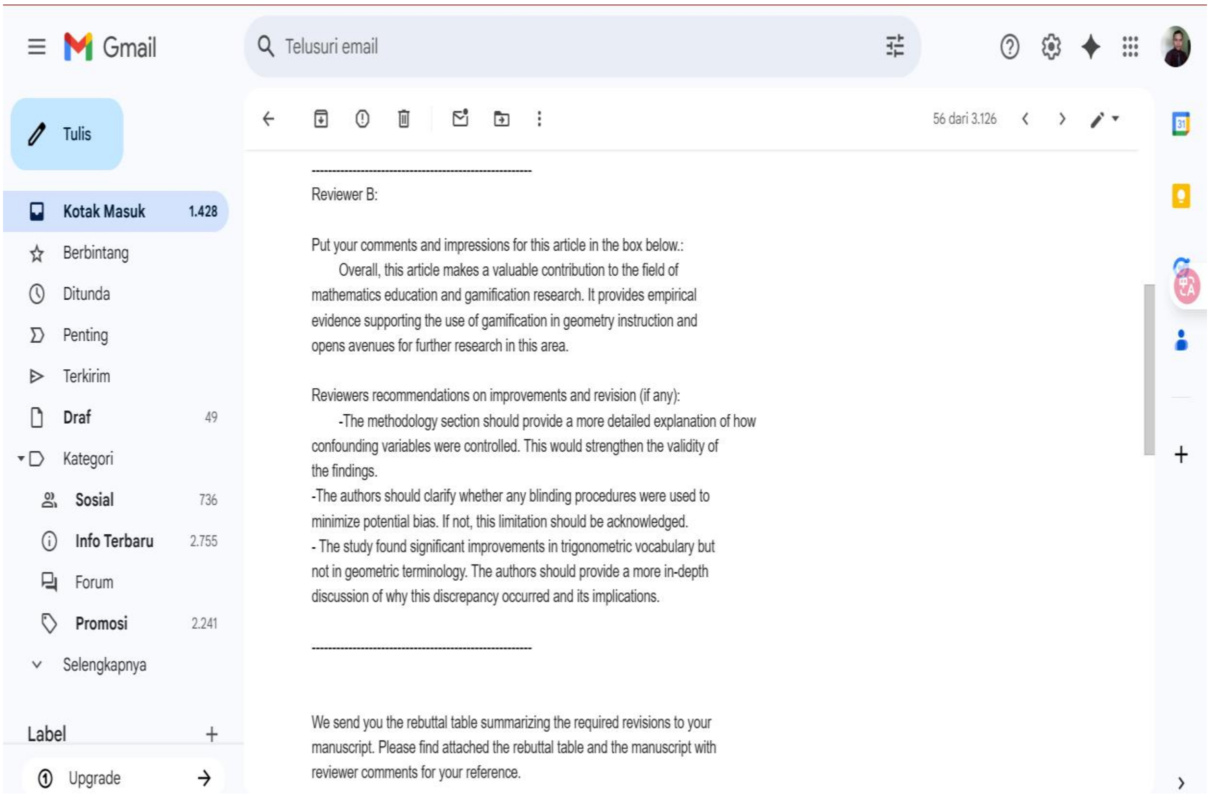
Put your comments and impressions for this article in the box below.:

Reviewers recommendations on improvements and revision (if any):

Reviewer B:

Put your comments and impressions for this article in the box below.:

Overall, this article makes a valuable contribution to the field of



Reviewer B:

Put your comments and impressions for this article in the box below.:

Overall, this article makes a valuable contribution to the field of mathematics education and gamification research. It provides empirical evidence supporting the use of gamification in geometry instruction and opens avenues for further research in this area.

Reviewers recommendations on improvements and revision (if any):

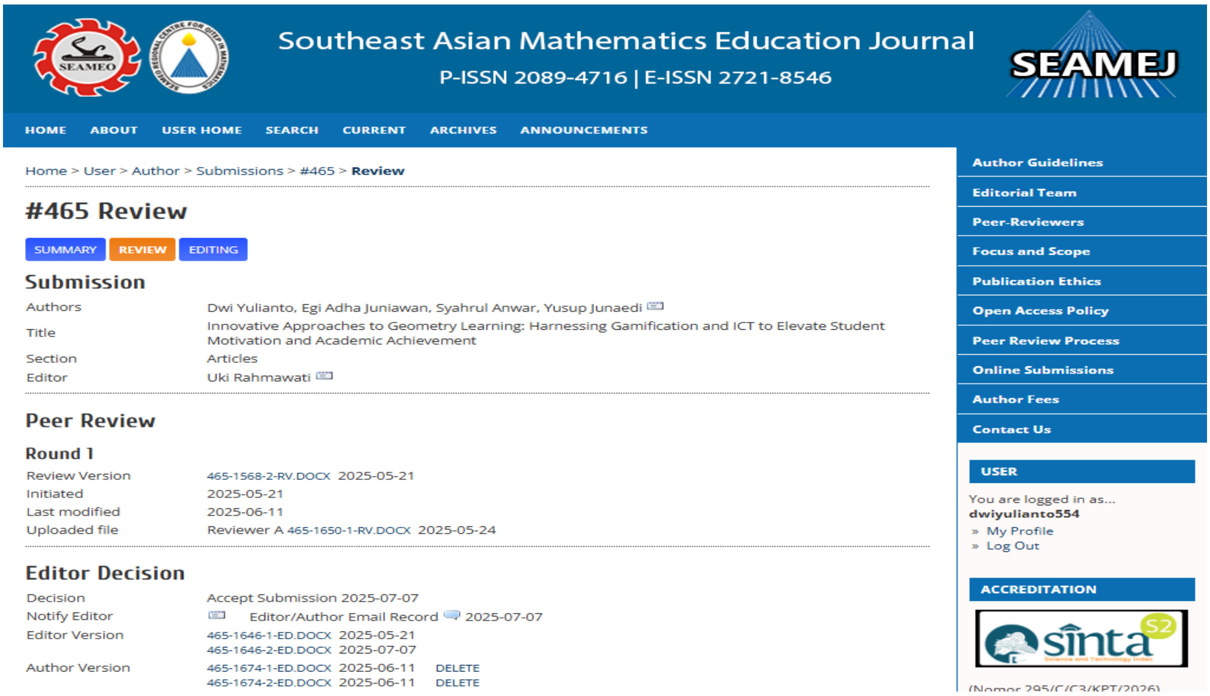
-The methodology section should provide a more detailed explanation of how confounding variables were controlled. This would strengthen the validity of the findings.

-The authors should clarify whether any blinding procedures were used to minimize potential bias. If not, this limitation should be acknowledged.

- The study found significant improvements in trigonometric vocabulary but not in geometric terminology. The authors should provide a more in-depth discussion of why this discrepancy occurred and its implications.

We send you the rebuttal table summarizing the required revisions to your manuscript. Please find attached the rebuttal table and the manuscript with reviewer comments for your reference.

3. Bukti konfirmasi submit revisi pertama, respons kepada reviewer, beserta artikel hasil revisi yang disubmit Kembali



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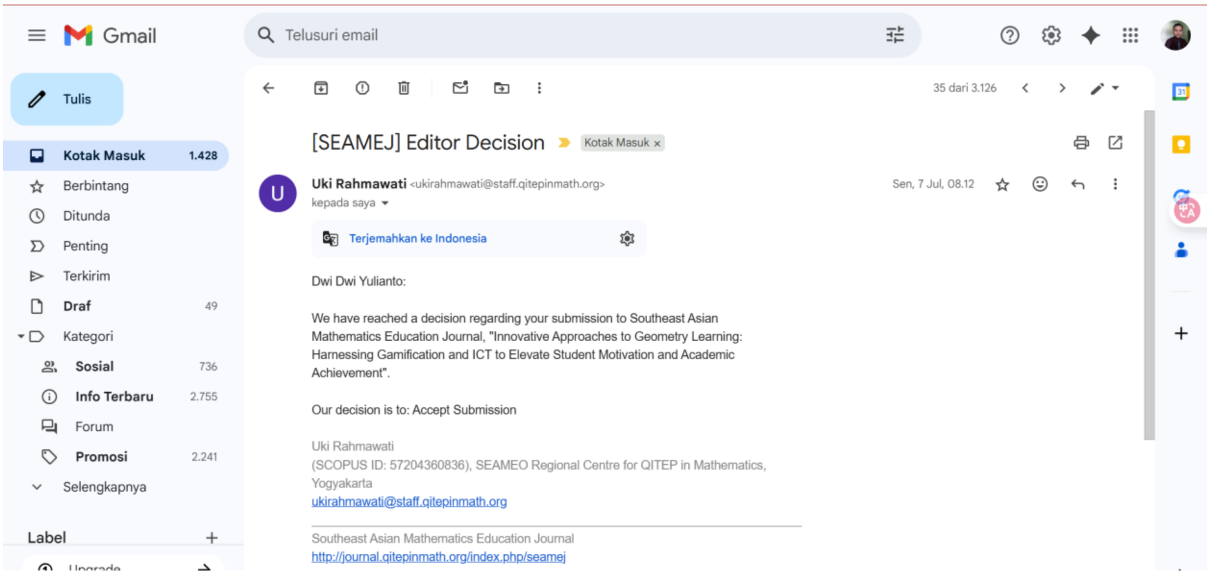

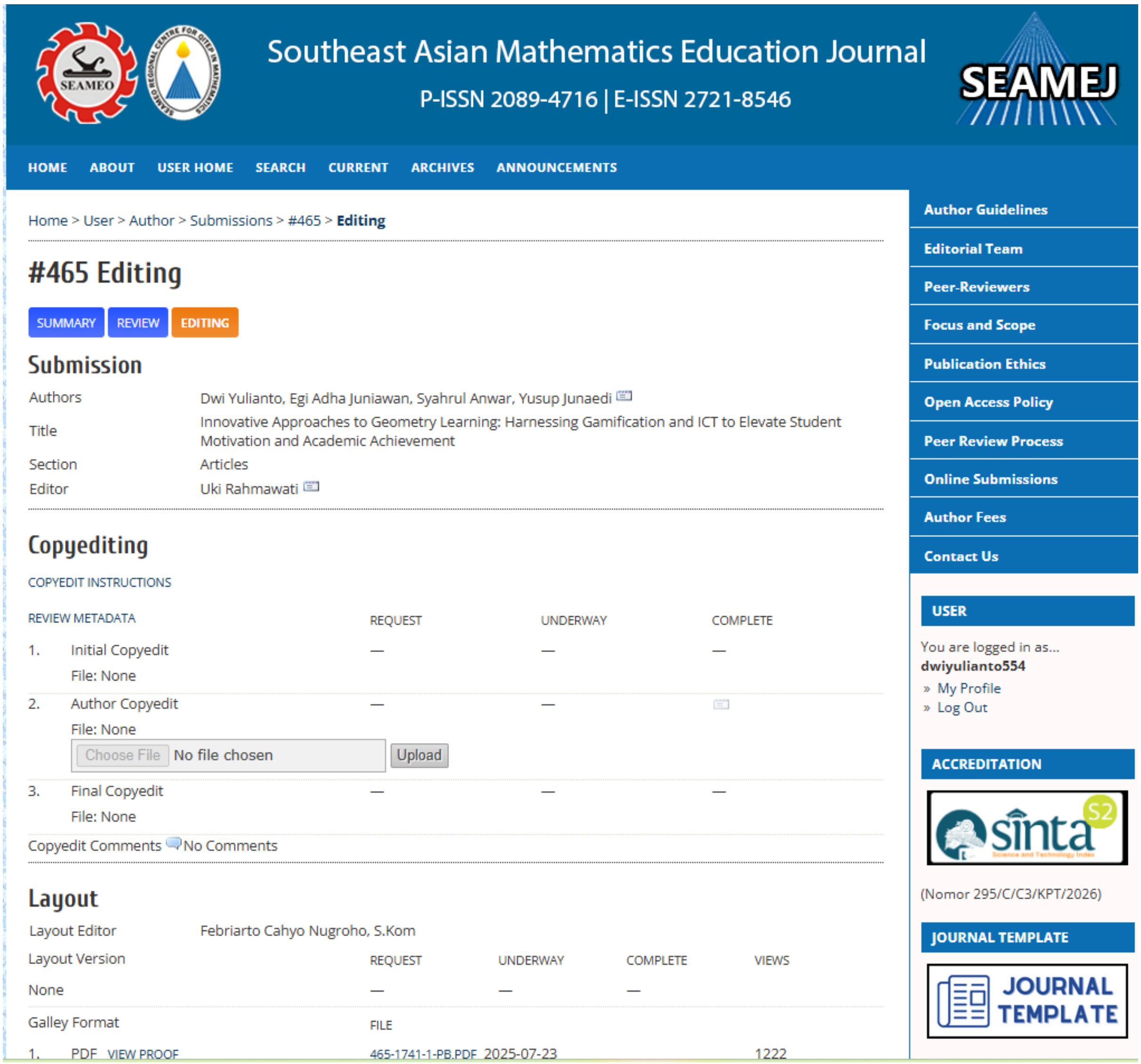

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#465 Editing

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Authors	Dwi Yulianto, Egi Adha Juniawan, Syahrul Anwar, Yusup Junaedi
Title	Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement
Section	Articles
Editor	Uki Rahmawati

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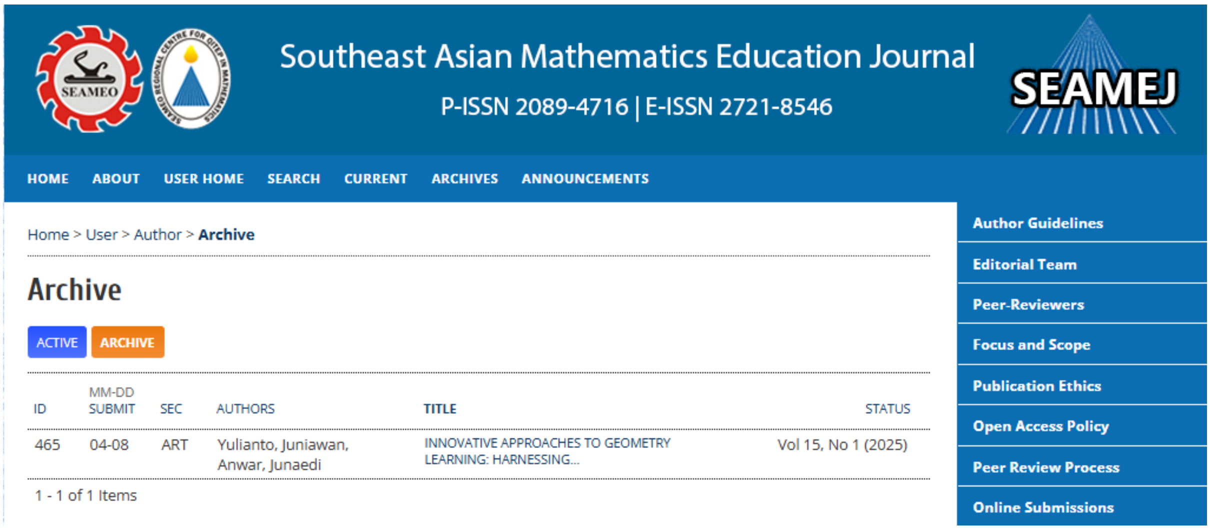

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Status	Published Vol 15, No 1 (2025)
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Last modified	2025-08-21

Submission Metadata

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Bio Statement	—
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Affiliation	Latansa Mashiro University
Country	—
Bio Statement	—
Name	Yusup Junaedi
Affiliation	Latansa Mashiro University
Country	—
Bio Statement	—

Title and Abstract

Title: Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement

Abstract: This study investigated the impact of a gamification-based didactic program on students' motivation, lexical availability, and academic achievement in high school geometry. Addressing concerns over low student engagement and performance in mathematics, often due to abstract content and passive pedagogy, the research integrates gamified elements into ICT-based geometry modules to foster active and meaningful learning. Anchored in Self-Determination Theory and the ARCS Motivation Model, the study employed a quasi-experimental design with a pretest-posttest control group, involving 89 tenth-grade students students (aged 15–16), consisting of 45 females (50.6%) and 44 males (49.4%), from a from a subsidized private school in Jakarta. Over a five-week trigonometry unit, the experimental group engaged with digital tools including *PhET* simulations, *Kahoot!*, and *TikTok*-based mnemonic media, all structured within the e-TPACK framework. Results showed a 23% improvement in academic performance based on pre- and post-test comparisons. Gamification significantly enhanced students'

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KEYWORDS

GeoGebra Geometry Indonesia Lesson Study Mathematical Modelling PISA RME STEAM STEM TPACK assessment design research mathematical literacy mathematics mathematics education meaningful learning numeracy primary school mathematics problem solving school mathematics technology

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Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement

Dwi Yulianto, Egi Adha Juniawan, Syahrul Anwar, Yusup Junaedi

Abstract

This study investigated the impact of a gamification-based didactic program on students' motivation, lexical availability, and academic achievement in high school geometry. Addressing concerns over low student engagement and performance in mathematics, often due to abstract content and passive pedagogy, the research integrates gamified elements into ICT-based geometry modules to foster active and meaningful learning. Anchored in Self-Determination Theory and the ARCS Motivation Model, the study employed a quasi-experimental design with a pretest-posttest control group, involving 89 tenth-grade students students (aged 15–16), consisting of 45 females (50.6%) and 44 males (49.4%), from a from a subsidized private school in Jakarta. Over a five-week trigonometry unit, the experimental group engaged with digital tools including *PhET* simulations, *Kahoot!*, and *TikTok*-based mnemonic media, all structured within the e-TPACK framework. Results showed a 23% improvement in academic performance based on pre- and post-test comparisons. Gamification significantly enhanced students' verbal expression in geometry, as reflected in increased word production and lexical diversity. Post-test motivation scores were also higher in the experimental group, indicating greater engagement. Moreover, a stronger correlation between motivation and academic achievement in this group reinforces gamification as a robust pedagogical strategy for enhancing learning outcomes in secondary mathematics education. These findings suggest that educators and curriculum developers should consider systematically integrating gamified, ICT-supported modules anchored in motivational theories such as SDT and ARCS into geometry instruction. Future implementations should prioritize culturally relevant game elements and adaptive technologies to sustain engagement, particularly among diverse student populations.

Keywords

Academic Achievement;Gamification;Geometry Education;Lexical Availability;Student Motivation

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Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement
1*Dwi Yulianto, 1Egi Adha Juniawan, 1Syahrul Anwar, 1Yusup Junaedi
1Faculty of Teacher Training and Education, Latansa Mashiro University, Indonesia.
1*dwiyulianto554@gmail.com
Abstract
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1 **Southeast Asia Mathematics Education Journal,** Volume 13, No 1 (2023)

Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement

Commented [R1]: Shorter your article. Do not more than 8000 words.

Abstract

This study investigates the impact of a gamification-based didactic program on students' motivation, lexical availability, and academic achievement in high school geometry. Addressing concerns over low student engagement and performance in mathematics often due to abstract content and passive pedagogy the research integrates gamified elements into ICT-based geometry modules to foster active and meaningful learning. Anchored in Self-Determination Theory and the ARCS Motivation Model, the study employed a quasi-experimental design with a pretest-posttest control group, involving 89 tenth-grade students from a subsidized private school in Jakarta. Over a five-week trigonometry unit, the experimental group engaged with digital tools including PhET simulations, Kahoot!, and TikTok-based mnemonic media, all structured within the e-TPACK framework. Results showed a 23% improvement in academic performance based on pre- and post-test comparisons. Gamification significantly enhanced students' verbal expression in geometry, as reflected in increased word production and lexical diversity. Post-test motivation scores were also higher in the experimental group, indicating greater engagement. Moreover, a stronger correlation between motivation and academic achievement in this group reinforces gamification as a robust pedagogical strategy.

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Keywords: Academic Achievement, Gamification, Geometry Education, Lexical Availability, Student Motivation.

Introduction

Mathematics is often perceived by students as difficult, abstract, and uninteresting (Yulianto et al., 2024; Forsblom et al., 2022; Bouchée et al., 2021). This perception contributes to heightened levels of mathematics anxiety (Mamolo, 2022; Wang et al., 2020) and low engagement in learning activities (Yulianto et al., 2024; Wang et al., 2020). PISA results indicate that many students struggle to grasp abstract concepts and to apply higher-order thinking skills in mathematics (OECD, 2023). This issue is further exacerbated by traditional teaching methods, which tend to be passive, discourage conceptual exploration, and lack meaningful interaction between students and learning materials (Yulianto et al., 2024). As a result, students' motivation to learn declines, leading to poor academic achievement (Wild, 2024; Dahri et al., 2024; Cao, 2023).

To address this challenge, an innovative constructivist-based approach is needed one that encourages active student participation. One increasingly adopted method in education is gamification, which refers to the use of game elements in non-game contexts (Priyadi et al., 2023). Gamification has been shown to have a positive impact on student engagement, motivation, and academic achievement across various subjects, including mathematics (Zeybek & Saygı, 2023). This concept is grounded in Self-Determination Theory (Deci & Ryan, 2020), which posits that game elements can enhance intrinsic motivation by fulfilling the psychological needs for autonomy, competence, and relatedness. Additionally, the ARCS Model of Motivation (Yulianto et al., 2024) suggests that the inclusion of challenges, rewards, and competition in gamified environments can enhance students' attention, relevance, confidence, and satisfaction in learning. While numerous studies have indicated that gamification can improve student motivation and comprehension, its overall effectiveness remains a topic of debate (Zeng et al., 2024; Mamekova et al., 2021; Bai et al., 2020). Some research has found that, if not properly designed, gamification may increase academic pressure, diminish intrinsic motivation, or yield only short-term effects on student engagement (Mamekova et al., 2021; Bai et al., 2020). Therefore, further research is necessary to better understand how optimally designed gamification strategies can provide sustainable benefits in mathematics education.

One of the most promising branches of mathematics for integration with gamification is geometry, as it involves spatial understanding and visualization skills that can be enhanced through games and visual simulations (Schutera et al., 2021; Schoevers et al., 2020). Gamified geometry instruction has the potential to improve students' spatial thinking, problem-solving abilities, and geometric analysis. In secondary school geometry classrooms, the use of gamification has been shown to increase student motivation and academic achievement by 23% (Fuentes-Riffo et al., 2023). The incorporation of spatial visualization tools, such as virtual environments and 3D printing, has led to a 25% improvement in spatial visualization skills among experimental groups (Herrera et al., 2024). However, there remains a gap in the literature regarding the effects of gamified learning on student motivation and academic performance, particularly within educational systems characterized by diverse social, economic, and pedagogical contexts. Most existing studies examine gamification in mathematics education more broadly, with limited research specifically addressing how gamification enhances geometry comprehension or how contextual factors such as students' learning style backgrounds and teaching methods influence learning outcomes. Therefore, this study aims to evaluate the impact of a gamified geometry learning unit on the motivation and academic performance of senior high school students at a subsidized private institution in Jakarta, Indonesia.

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Theoretical Support

Motivation

Motivation drives individuals to achieve goals through initiative, perseverance, and action (Gagné & Hewett, 2025; Cheng, 2023; Holding et al., 2021). Deci and Ryan (2020) emphasize the role of motivation in fostering learning engagement and resilience. Motivation is generally categorized into two types: intrinsic, which arises from personal interest, and extrinsic, which is influenced by external factors such as rewards. Extrinsic motivation depends on outcomes that are separate from the activity itself (Morris et al., 2022; Guay, 2021). In the context of mathematics education, motivation is shaped by task design, content relevance, peer interaction, assessment practices, teacher feedback, and instructional materials (Aust et al., 2024; Alipour et al., 2023; Kaplar et al., 2022; Cevikbas & Kaiser, 2021). It encompasses both interest and persistence in academic tasks (Gagné & Hewett, 2025; Cheng, 2023; Holding et al., 2021).

Gamification has been shown to enhance motivation by creating more enjoyable learning experiences through elements such as points, badges, and leaderboards which, in turn, can improve student motivation and academic achievement (Jaramillo-Mediavilla et al., 2024;

Ratinho & Martins, 2023). Zhang et al. (2021) found that digital tools support the development of positive attitudes toward mathematics. Additionally, emotional factors, self-perceptions, and success expectations play significant roles in student engagement (Tao et al., 2022; Wang et al., 2021). Negative attitudes toward mathematics are often rooted in past negative experiences, stereotypes, and perceptions of difficulty (Woitzel & Alves, 2024; McKenzie et al., 2022). Berger et al. (2021) demonstrated that students' perceptions of task value and their expectations for success are key determinants of academic achievement (Aust et al., 2024; Alipour et al., 2023; Kaplar et al., 2022; Cevikbas & Kaiser, 2021). Gamification motivates students by offering challenges, rewards, and opportunities for interaction, which enhance curiosity, self-efficacy, and engagement in learning (Kaya & Ercag, 2023).

Gamification

Gamification in mathematics education involves the application of game elements such as points, challenges, instant feedback, and competition to create a more engaging and participatory learning experience (Zeybek & Saygı, 2023; Jaramillo-Mediavilla et al., 2024). This strategy aims to enhance student engagement and motivation by incorporating mechanisms that trigger enjoyment and a sense of achievement rather than relying solely on conventional instructional methods (Fuentes-Riffo et al., 2023). This approach aligns with Self-Determination Theory (Deci & Ryan, 2020; Guay, 2021), which emphasizes the importance of fulfilling students' basic psychological needs autonomy, competence, and relatedness in order to foster intrinsic motivation. Gamification also reflects the principles of the ARCS model (Attention, Relevance, Confidence, Satisfaction) by enhancing students' attention, the relevance of content, confidence, and satisfaction in the learning process (Kaya & Ercag, 2023; Zhang et al., 2021).

Mathematics is often perceived by students as difficult and abstract, which contributes to low learning motivation especially when taught through traditional, passive instructional methods (Kaplar et al., 2022; Tao et al., 2022). Gamification offers an alternative approach by transforming mathematics learning into a more interactive and exploratory process. Unlike game-based learning, which centers on the use of games as the primary instructional tool, gamification focuses on integrating game elements into learning activities to enhance both motivational and cognitive aspects (Zeng et al., 2024; Bai et al., 2020). Research indicates that students in gamified classrooms demonstrate greater perseverance, improved teamwork, and enhanced problem-solving skills (Ratinho & Martins, 2023; Forsblom et al., 2022). Digital platforms that support gamification also enable more personalized and adaptive learning experiences, which positively influence learning outcomes (Wang et al., 2021; Zhang et al., 2021). By shifting from rote memorization to dynamic conceptual exploration, gamification has proven to be an effective and innovative strategy for significantly improving students' motivation, engagement, and overall mathematics achievement (Alipour et al., 2023; Jaramillo-Mediavilla et al., 2024; Zeng et al., 2024).

Lexical Availability

Lexical availability (LD) measures how students access and understand vocabulary while avoiding repetition. It is regarded as an indicator of writing ability and can be assessed using indices such as MTLD and vocd-D (Shibata, 2021; Rasti-Behbahani & Shahbazi, 2020) in game-based geometry learning. In the context of digital mathematics education, LD serves as a tool to analyze how students internalize concepts through interaction, real-time feedback, and motivational mechanisms embedded within game-based learning applications (Shi, 2022; Vankúš, 2021; Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). Game-based learning environments enable students to learn through scenarios, simulations, and time-based challenges (Shi, 2022). LD plays a vital role in evaluating how students recall and apply geometric vocabulary in interactive tasks. For instance, in an educational geometry game, students may be asked to identify shapes, classify angles, or rapidly apply transformation concepts. The frequency and distribution of geometric terms used in student interactions can be utilized to assess their understanding.

Gamification enhances student engagement by stimulating memory through time-based challenges and reward systems such as points, levels, and badges. Vocabulary retrieval in game-based environments is often more effective than in traditional methods due to factors such as urgency, adaptive repetition, and visual feedback (Rasti-Behbahani & Shahbazi, 2020). Game-based mathematics learning applications frequently provide real-time feedback, allowing students to immediately see whether their answers are correct (Shi, 2022; Vankúš, 2021; Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). LD helps evaluate the effectiveness of such feedback in reinforcing conceptual understanding (Shibata, 2021). For example, in games that require students to identify properties of geometric shapes, immediate feedback accelerates the assimilation of terms such as “right angle,” “line of symmetry,” or “diagonal.” Vocabulary storage and retrieval are influenced by pronunciation, spelling, syntax, and conceptual meaning. In game-based learning, vocabulary reinforcement is facilitated through interactive narratives, audiovisual elements, and adaptive repetition features, which help students connect geometric concepts with their practical applications.

Motivation is a key factor in the success of game-based learning (Yulianto et al., 2024). Through gamification, LD can be used to assess how challenges and incentives within learning applications enhance student engagement and mastery of concepts (Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). Students who encounter geometry challenges within ranking systems or competitions tend to be more motivated to enrich their vocabulary in order to achieve higher scores (Shi, 2022; Vankúš, 2021). The interest-centered method in LD studies, in which students list terms related to a theme within a limited time, can be adapted into game-based challenges such as interactive quizzes or timed geometric puzzles. In this way, game-based mathematics learning applications not only increase students’ motivation but also broaden their vocabulary in a more meaningful and applicable context.

Methods

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Type and Approach of the Study

This study employs a quantitative approach using a quasi-experimental method, specifically adopting a pre-test post-test control group design to evaluate the impact of gamification in geometry learning on students’ motivation and academic achievement. This method facilitates a comparison between an experimental group, which receives instruction through gamified learning, and a control group, which is taught using conventional methods. The study was

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conducted in a secondary school located in the Special Capital Region (DKI) of Jakarta in 2024, involving participants divided into two groups: the experimental group, which learned geometry through a gamification-based platform, and the control group, which received instruction using traditional, non-gamified methods.

Commented [R9]: Do not translate the name of area.

The research consisted of four main stages. The first stage was the pre-test (O_1, O_3), during which both groups completed a geometry test and the MotLearn-Q survey to assess their initial levels of motivation and academic performance. The second stage involved the intervention (X), where the experimental group engaged with a gamification platform featuring interactive elements and real-time feedback designed to enhance learning engagement, while the control group continued learning through conventional means. The third stage was the post-test (O_2, O_4), wherein both groups took the same test again to evaluate any changes in motivation and academic performance. The final stage involved data analysis, in which pre-test and post-test results were compared using inferential statistical tests, such as t-tests or ANCOVA, to determine the effectiveness of gamification and explore the relationship between student motivation and academic achievement.

Table 1
Quasi-Experimental One-Group Pre-Test Post-Test Design

Group	Pre-test	Intervensi Gamifikasi	Post-test
Experimental (E)	O_1	X	O_2
Control (C)	O_3	–	O_4

Participants and Sample Selection Criteria

This study involved 10th-grade students who were enrolled in a geometry course at a government-subsidized secondary school in DKI Jakarta. The research population consisted of all 10th-grade students at the school, totaling 89 individuals. To ensure a representative sample and minimize bias, a stratified random sampling technique was employed, stratifying the sample based on gender and academic achievement level. From the population, 45 students were selected for the experimental group, which received the gamified instructional intervention. This group included 25 females (55.6%) and 20 males (44.4%). Meanwhile, the remaining 44 students were assigned to the control group, which received conventional instruction without gamification. The control group comprised 24 females (54.5%) and 20 males (45.5%), maintaining a gender distribution nearly equivalent to that of the experimental group. Stratification ensured that the proportions of gender and academic level in the sample accurately reflected those in the population. Inclusion criteria required students to be enrolled in the geometry course and willing to participate in the study. Exclusion criteria involved students who were not consistently present during the instructional sessions or who faced limitations in accessing the technology required for the intervention. To control for confounding variables, factors such as learning styles, access to technology, and previous experience with gamification were considered. Student participation was entirely voluntary, supported by parental consent and formal approval from the school's academic department.

Commented [R10]: Why you choose this participants.

Table 2
Demographic Characteristics of the Participants

Variable	Category	n	%
Gender	Male	20	44.4%

	Female	25	55.6%
Academic Achievement Level	Low (< 60)	8	17.8%
	Medium (60–79)	21	46.7%
	High (≥ 80)	16	35.5%
Technology Access	Own personal device	37	82.2%
	School-provided device	6	13.3%
	Limited/borrowed device	2	4.5%
Frequency of Technology Use *(in Learning Activities)*	Never (< 1x/week)	3	6.7%
	Rarely (1–2x/week)	10	22.2%
	Often (3 – 4x /week)	20	44.4%
	Very often (≥ 5x/week)	12	26.7%
Prior Experience with Gamification	No experience	18	40.0%
	Has used gamification	27	60.0%
Learning Style	Visual	14	31.1%
	Auditory	9	20.0%
	Kinesthetic	12	26.7%
	Mixed (Visual – Auditory – Kinesthetic)	10	22.2%
Type of Motivation	Intrinsic	26	57.8%
	Extrinsic	19	42.2%

Assumption Testing for Pre-Test and Post-Test

To control for the influence of external factors on the research outcomes, both a pre-test and a post-test were administered. The pre-test results were utilized as covariates in the ANCOVA analysis to ensure that any observed differences in post-test scores were genuinely attributable to the gamification intervention. Before conducting the ANCOVA, two key assumptions were tested: 1) Normality of Data – Assessed using a Q-Q Plot and the Shapiro-Wilk Test. If the data points on the Q-Q Plot align closely with the diagonal line and the *p*-value is greater than 0.05, the data are considered to be normally distributed; and 2) Homogeneity of Variance – Evaluated using a Boxplot and Levene's Test. If the *p*-value exceeds 0.05, the variances across groups are considered homogeneous. The distribution of pre-test scores was analyzed using the Shapiro-Wilk Test to assess data normality, while Levene's Test was applied to verify the equality of variances between the experimental and control groups.

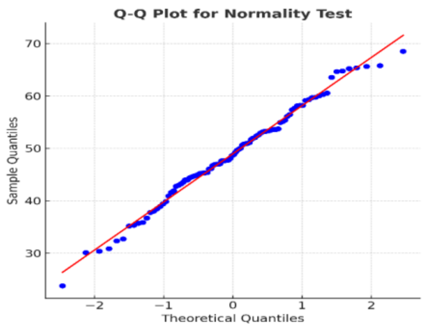

Figure 1. Data Normality

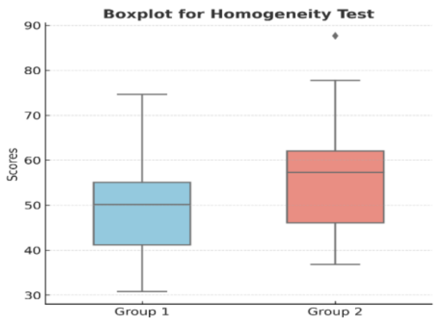

Figure 2. Homogeneity of Variance

The Shapiro–Wilk test indicated that the data in both groups were normally distributed ($p > 0.05$). Furthermore, Levene's Test yielded a p-value of 0.271, suggesting that the variances between the two groups were homogeneous ($p > 0.05$). As presented in Table 3, the Shapiro–

Wilk test confirmed that all data sets were normally distributed ($p > 0.05$). Additionally, Levene's Test produced a p-value of 0.271, indicating that the variances between groups were homogeneous ($p > 0.05$).

Table 3

Descriptive Statistics of Students' Pre-Test Scores

Variable	Category	n	Mean	SD	Shapiro–Wilk (p)	Levene's Test (p)
Gender	Male	44	67.8	8.5	0.078 (Normal)	0.293 (Homogeneous)
	Female	45	66.5	9.2	0.091 (Normal)	
Academic Level	High	30	75.4	6.8	0.061 (Normal)	0.256 (Homogeneous)
	Medium	30	68.1	7.9	0.089 (Normal)	
	Low	29	60.7	8.3	0.102 (Normal)	
Learning Style	Visual	28	69.5	7.8	0.073 (Normal)	0.317 (Homogeneous)
	Auditory	30	66.2	8.6	0.081 (Normal)	
	Kinesthetic	31	64.8	9.1	0.094 (Normal)	
Type of Motivation	Intrinsic	42	71.2	7.5	0.068 (Normal)	0.229 (Homogeneous)
	Extrinsic	47	63.9	8.9	0.084 (Normal)	

Instruments and Data Collection

This study employed three primary instruments to measure the variables under investigation. The Learning Process Motivation Evaluation Questionnaire (MotLearn-Q), consisting of 23 items, was used to assess students' intrinsic, extrinsic, and overall motivation. Originally validated in Spain, the instrument demonstrated very high reliability (Cronbach's alpha = 0.93). In the present study, MotLearn-Q was administered to 248 students, yielding similarly high reliability ($\alpha = 0.925$), with subscale reliabilities of intrinsic motivation ($\alpha = 0.912$), extrinsic motivation ($\alpha = 0.918$), and global motivation ($\alpha = 0.925$). These findings confirm the reliability of MotLearn-Q in assessing student motivation in a gamified learning context. The Lexical Availability Test demonstrated strong validity through both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), supported by good model fit indices (CFI = 0.91, TLI = 0.89, RMSEA = 0.06). These analyses confirmed the structure encompassing the categories of geometry, trigonometry, and emotions related to geometry. Content validity was reinforced by Aiken's V index of ≥ 0.85, indicating a high level of expert agreement. Predictive validity was evidenced by a significant correlation with geometry exam scores ($r = 0.62$, $p < 0.001$). The instrument also demonstrated high reliability, with Cronbach's alpha = 0.88, indicating strong internal consistency and temporal stability as shown by a test-retest correlation ($r = 0.81$, $p < 0.001$). Furthermore, item difficulty analysis ($0.30 \leq p \leq 0.70$) confirmed that the instrument effectively discriminated between students with varying levels of lexical availability. The Geometry Test was used to evaluate students' understanding of geometric concepts within a gamified learning environment. The test employed a 7-point grading scale aligned with Chilean evaluation standards. Students were considered to have passed if they obtained a minimum score of 4 ($\geq 60\%$, equivalent to at least 12 correct responses out of 20 items). The distribution of scores was expected to follow a normal curve, with an average range between 4.5 and 5.2, a standard deviation between 0.8 and 1.1, and a pass rate of approximately 70–80%. This test served as an academic performance indicator of students' mastery of geometric content in a gamified learning setting.

Research Procedure

Commented [R11]: Make your procedure in flowchart.

In this study, a sequence of instructional activities was designed to be implemented over five weeks within the trigonometry unit as part of the geometry curriculum. The instructional approach employed is based on the e-TPACK model, an extension of the Technological Pedagogical Content Knowledge (TPACK) framework. This model emphasizes the integration of Information and Communication Technology (ICT) in classroom instruction. The e-TPACK model incorporates key elements such as digital technologies, Bloom's Digital Taxonomy, and emotional engagement enhanced through gamification. Gamification is applied through a reward system intended to motivate students at each stage of learning. Moreover, this approach aligns learning activities with students' cognitive levels based on Bloom's Digital Taxonomy, thereby enabling learners to engage in progressively complex thinking from basic to higher-order skills. To ensure the model's effectiveness, this study systematically organizes instructional steps, as detailed in Table 4. The table outlines the stages of e-TPACK implementation in the teaching of trigonometry.

Table 4

Instructional Sequence of the e-TPACK Model

Activity	Bloom's Taxonomy	Technology	Emotions Evoked
Independent Research: Students search for information on trigonometric ratios and similarity. They gather materials, highlight key points, and summarize their findings in a notebook.	Remember, Understand, Apply	Google	Interest, Curiosity, Awe
Concept Mapping: Students create a concept map based on their research, then explain and compare their results with peers.	Analyze, Create, Connect, Explain	MindMeister, Cmap Tools	Enthusiasm, Confidence, and Interest
Graph Exploration: Students analyze graphs and angles in a circle, relate angles to trigonometric ratios (sin, cos, tan), and make conjectures about emerging patterns using an interactive simulator.	Analyze, Connect, Predict	PhET Trig Tour	Awe, Approval, Curiosity, Interest
Triangle Side Relations: Students identify relationships among the sides of right-angled triangles and apply trigonometric principles to form appropriate ratios.	Connect, Identify, Predict	Cerebriti Math Games	Confidence, Surprise, Curiosity
Memorization Through Song: Students memorize basic trigonometric values using songs on TikTok and apply them to solve problems.	Remember, Apply	TikTok Educational	Joy, Enthusiasm, Entertainment, Awe
Interactive Quiz: Students complete a Kahoot! quiz to assess their understanding. High scores earn bonus points in assessment.	Recognize, Analyze, Identify	Kahoot!	Curiosity, Joy, and Confidence
Final Evaluation: Students take a test on trigonometric ratios and their applications in various problems.	Remember, Understand, Apply, Analyze, Evaluate	Trigonometry Test	Confidence, Optimism, Approval

The Gamification Approach in Geometry Learning

The gamification approach in geometry learning, as described in this text, involves three main strategies aimed at increasing student engagement: rewards, interactions, and penalties. Within the reward system, students earn emojis as a form of appreciation for their performance in completing learning activities. Interactions occur both among students as players and between students and the teacher acting as the adjudicator. These interactions foster social engagement and collaboration throughout the learning process. Meanwhile, the penalty system is implemented by deducting previously earned emojis when students commit predefined violations. At the end of the module, students can redeem their collected emojis for specific benefits, as outlined in Table 5. This approach differs significantly from traditional methods of teaching geometry, which tend to focus more on understanding trigonometry through calculations involving angles and distances using the Law of Sines and the Law of Cosines. In conventional methods, students are typically assigned exercises that emphasize the mechanical manipulation of mathematical formulas or rote learning, wherein they merely follow calculation steps without fully grasping the practical applications. As a result, for some students, such learning may feel abstract and less relevant to real-life contexts. In this regard, gamification emerges as a more engaging and effective solution by offering a learning experience that is interactive, meaningful, and motivational, encouraging students to develop a deeper understanding of geometric concepts, particularly in relation to fields such as physics, engineering, and astronomy.

Table 5

Benefits of Emojis Collected by Students

Number of Emojis Collected	Benefit
More than 15 emojis	Maximum bonus score (7.0) for the subject.
Between 10 and 14 emojis	Additional 5 points for any evaluation during the semester.
Between 5 and 9 emojis	Removal of the lowest score in process-based tests.
Between 1 and 4 emojis	Additional 2 points for unit assessments.

As shown in Table 5, the more emojis students collect, the greater the academic benefits they receive in the form of bonus points or score improvements in their evaluations.

Statistical Analysis and Research Hypotheses

This study employed a range of statistical methods to measure the impact of gamification on geometry instruction. A *paired t-test* was used to assess improvements in academic achievement (H_1) and students' word production (H_2) by comparing the means of pre-test and post-test scores. The *Wilcoxon Signed-Rank Test* was applied to examine the increase in students' lexical availability index (H_3). Meanwhile, the *Pearson Correlation Test* was utilized to analyze the relationship between global motivation and academic performance (H_5). To ensure the consistency and reliability of the research instruments, *Cronbach's Alpha Reliability Analysis* was conducted. Through this approach, the study evaluates the effectiveness of gamification in enhancing students' understanding of geometry, as well as their motivation and linguistic abilities. Gamification in geometry instruction is expected to yield significant positive effects across various academic and motivational dimensions. Accordingly, this study tests five main hypotheses that reflect the potential benefits of gamification in enriching the learning experience.

H_1 : Gamification enhances academic achievement.

Gamification is considered effective in improving students' understanding and academic performance if the mean post-test score in the experimental group is higher than that of the control group ($\bar{x}$*_post_eksperimental* > $\bar{x}$*_post_control*).

H_2 : Gamification increases word production in geometry explanations.
Gamification contributes to enriching students' linguistic expression if the number of words in the post-test responses of the experimental group exceeds that of the control group ($\bar{x}$*_post_eksperimental* > $\bar{x}$*_post_control*).

H_3 : Gamification expands students' vocabulary.
Gamification supports vocabulary development if the increase in the Personal Lexical Availability Index (LAI) in the experimental group is greater than in the control group (*ΔLAI_eksperimental* > *ΔLAI_control*).

H_4 : Gamification enhances student motivation.
Gamification improves student engagement in learning if the post-test motivation score in the experimental group is higher than in the control group (*motivation_post_eksperimental* > *motivation_post_control*).

H_5 : There is a relationship between motivation and academic achievement in gamified learning.
Gamification is instrumental in fostering both engagement and academic success if the correlation between global motivation and academic achievement in the experimental group is stronger than in the control group (*r_eksperimental* > *r_control*).

Results and Discussion

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To test the first hypothesis (H_1), which posits that gamification enhances academic achievement, a comparative analysis of pre-test and post-test scores was conducted for both the experimental and control groups. A paired-samples t-test was employed to determine whether a significant difference existed in academic performance before and after the gamification intervention. Prior to the analysis, the Shapiro–Wilk normality test was applied to ensure that the data were normally distributed. The results indicated that the p-value for the pre-test was 0.062 and for the post-test was 0.189, confirming that the assumption of normality was satisfied. Subsequently, the results of the Student's t-test revealed a p-value of 0.000, leading to the rejection of the null hypothesis (H_0). This finding demonstrates a significant improvement in academic performance following the implementation of gamification in geometry instruction (see Table 6).

Table 6
Results of Paired-Samples t-Test for Academic Achievement

Group	Comparison	M	SD	MSE	CI	t	df	Sig.	Cohen's d
Experiment Class	Pre-test vs. Post-test	-11.572	6.630	0.988	[-13.636, -9.652]	-11.781	44	0.000	1.141
Control Class	Pre-test vs. Post-test	-10.851	6.400	0.956	[-12.950, -8.750]	-11.230	43	0.000	1.082

Table 6 presents the results of the paired-samples t-test for academic achievement. Both the experimental group (M = -11.572, d = 1.141) and the control group (M = -10.851, d = 1.082) showed significant improvements ($p < 0.05$) from pre-test to post-test. However, the experimental group demonstrated a slightly greater increase, as evidenced by a higher mean difference and a larger effect size. These results suggest that the gamification intervention had a more substantial impact on academic achievement compared to conventional instructional methods. Therefore, the findings support the hypothesis that gamification enhances academic achievement by creating a more engaging and effective learning environment.

Lexical Analysis

The second hypothesis (H_2) posits that gamification enhances word production in geometry explanations, which can be substantiated if the number of words in the post-test of the experimental group exceeds that of the control group. Initially, the number of words generated by students during both phases of the study was analyzed. To compare the average number of words produced by students across the three primary domains of interest, emotions, geometry, and trigonometry, a series of comparative analyses was conducted. Subsequently, statistical analyses were applied to calculate the Lexical Availability Index (LAI) and the Proportional Lexical Availability Index (LAIp) using the Dispogen software (version 2014). In this study, students were given a lexical availability test to identify words associated with the emotional domain. The prompt provided was: *"What emotions do you associate with geometry?"* Additionally, for the geometry and trigonometry domains, students were asked to generate a list of terms related to each concept (see Table 7). Statistical analyses were carried out while considering the normality of data distribution. The Student's t-test was applied for normally distributed data, while the Wilcoxon test was used for non-normally distributed data.

Table 7

Lexical Availability Test Results and Statistical Analysis

Area of Interest	$\bar{x} \pm$ SD (Experiment)	$\bar{x} \pm$ SD (Control)	W	p-value (Normality)	Statistical Test	p-value
Emotion & Geometry	12.4 ± 3.1	12.2 ± 3.0	0.967	0.067 (normal)	t-test	0.215
Geometry	15.8 ± 4.2	15.5 ± 3.6	0.972	0.082 (normal)	t-test	0.089
Trigonometry	9.6 ± 2.8	5.81 ± 2.5	0.891	0.013 (not normal)	Wilcoxon test	0.000

Table 7 shows that the increase in lexical availability was significant only in the trigonometry domain ($p = 0.000$), where the experimental group (9.6 ± 2.8) outperformed the control group (5.81 ± 2.5). Meanwhile, for Emotion & Geometry and Geometry, the differences between the experimental and control groups were not statistically significant ($p > 0.05$). This suggests that the applied instructional method primarily impacted the understanding of trigonometric concepts, with a lesser effect on emotional associations and geometrical understanding. Furthermore, as shown in Table 8, the statistical analysis indicates a significant increase in trigonometric lexical availability in the experimental group compared to the control. The average number of words in the experimental group rose from 255 (M = 5.79) to 492 (M = 10.93) ($p = 0.000$), whereas the control group showed only a slight increase from 250 (M = 5.75) to 258 (M = 5.81) ($p > 0.05$). Conversely, in the domains of emotion and geometry, neither the experimental nor the control group exhibited significant changes ($p > 0.05$). These findings confirm the effectiveness of context-based instructional strategies in enhancing lexical richness in trigonometry, while their influence on the domains of emotion and geometry remains limited.

Table 8

Words Produced in Each Centre of Interest

Category	Group	Pre-test (N, M, SD)	Post-test (N, M, SD)	ΔM	p-value
Emotion	Experimental	244 (5.42, 1.21)	211 (4.68, 1.15)	-0.74	0.084
	Control	240 (5.40, 1.18)	238 (5.38, 1.17)	-0.02	0.915
Geometry	Experimental	557 (12.37, 2.54)	524 (11.64, 2.48)	-0.73	0.076
	Control	550 (12.40, 2.50)	545 (12.35, 2.49)	-0.05	0.967
Trigonometry	Experimental	255 (5.79, 1.32)	492 (10.93, 1.75)	+5.14	0.000
	Control	250 (5.75, 1.30)	258 (5.81, 1.33)	+0.06	0.834

The analysis of Table 8 reveals a statistically significant increase in trigonometric lexical items within the experimental group (ΔM = +5.14, $p = 0.000$), while the control group did not exhibit a meaningful change (ΔM = +0.06, $p = 0.834$). In contrast, the emotion and geometry categories did not show significant differences ($p > 0.05$), indicating that the intervention specifically impacted trigonometry. This improvement partially supports the second hypothesis, as evidenced by the higher average number of words in the post-test. The absence of significant changes in the emotion and geometry categories may be attributed to the possible substitution of words during the post-test or could be influenced by participants' varying levels of motivation throughout the study.

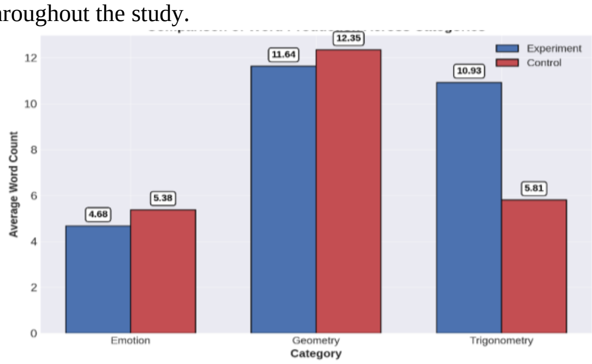

Figure 3. Compararison of Word Production Across Categories

Lexical Availability Index in Emotions, Geometry, and Trigonometry

The Lexical Availability Index (LAI) was employed to analyze lexical changes across three main categories: emotions related to geometry, geometric terminology, and trigonometric terminology. The results indicate that the intervention had varying impacts across these categories.

1. Emotions Related to Geometry.

   In the experimental group, there was a significant shift from negative to positive lexical items following the intervention. Prior to the intervention, the most dominant words were *fear* (32.7%), *sadness* (30.2%), and *laziness* (26.2%). After the intervention, these words showed a marked decrease, accompanied by a notable increase in positive lexical items such as *happiness* (41.1%), *joy* (30.6%), and *thrill* (21.4%). In contrast, the control group exhibited no statistically significant change ($p > 0.05$). Negative words remained predominant, including *fear* (31.5%), *sadness* (28.9%), and *laziness* (25.1%), while the increase in positive terms such as *happiness* (39.5%), *joy* (29.8%), and *thrill* (20.5%) did not represent a meaningful difference.

2. Geometric Terminology.

   In the category of geometric terminology, neither the experimental nor the control group demonstrated significant changes ($p > 0.05$). In the experimental group, there was a slight increase in the frequency of geometric terms. In the pre-test, the most frequently mentioned words were *square* (45.6%), *triangle* (41.3%), and *area* (39.6%). After the intervention, minor shifts were observed, with *angle* (46.8%), *triangle* (45.8%), and *square* (41.5%) becoming more prominent. In the control group, changes were minimal. The dominant terms remained *square* (44.5%), *triangle* (40.2%), and *area* (38.5%) in the pre-test, and *angle* (45.5%), *triangle* (44.7%), and *square* (40.5%) in the post-test. These results suggest that the intervention had no substantial effect on students' geometric terminology.

3. Trigonometric Terminology.

   In the category of trigonometric terminology, the experimental group demonstrated a significant increase in the number of terms ($p = 0.000$). The most dominant words in the pre-test were *triangle* (60.5%), *geometry* (26.4%), and *number* (24.9%). After the intervention, there was a noticeable shift, with a significant increase in the terms *triangle* (49.5%), *cosine* (48.2%), and *sine* (46.7%). In contrast, the control group did not show any significant change ($p > 0.05$), with the dominant pre-test terms remaining *triangle* (59.0%), *geometry* (25.5%), and *number* (24.0%). The post-test revealed only minimal changes, with *triangle* (48.2%), *cosine* (47.0%), and *sine* (45.5%) being the most common.

To test hypothesis H_3, a statistical analysis was conducted by comparing the mean differences in the Lexical Availability Index (LAI) before and after the intervention between the experimental and control groups. An independent t-test analysis revealed that gamification significantly improved the LAI in the trigonometric category ($t(87) = 3.28$, $p = 0.0015$), with a greater increase observed in the experimental group (ΔMean = 0.109) compared to the control group (ΔMean = 0.044, Cohen's d = 0.695). Conversely, in the geometry category, no significant difference was found ($t(87) = 0.59$, $p = 0.555$), suggesting that gamification had a stronger impact on expanding trigonometric vocabulary than geometric terminology.

Table 9

Independent T-Test Analysis for Trigonometry and Geometry Categories

Category	Group	ΔMean (Post - Pre)	SD Post	n	t-value	p-value	Cohen's d
Trigonometry	Experimental	0.109	0.095	45	3.28	0.0015	0.695
	Control	0.044	0.092	44			
Geometry	Experimental	0.023	0.098	45	0.59	0.555	0.126
	Control	0.011	0.093	44			

As shown in Table 9, gamification significantly increased the Lexical Availability Index (LAI) for the trigonometry category ($t(87) = 3.28$, $p = 0.0015$), with a greater improvement in the experimental group (ΔMean = 0.109) than in the control group (ΔMean = 0.044, $d = 0.695$). In contrast, no significant difference was found in the geometry category ($t(87) = 0.59$, $p = 0.555$), underscoring the stronger effectiveness of gamification in enhancing trigonometric vocabulary.

Table 10 below presents the top three most available words in each of the three main categories: emotion, geometric terminology, and trigonometric terminology, based on the pre-test and post-test results.

Table 10

Top Three Most Available Words by Category of Interest

Category	Group	Pre-Test (LAI)			Post-Test (LAI)		
		Word 1	Word 2	Word 3	Word 1	Word 2	Word 3
Emotion	Experimen	Fear (0.327)	Sadness (0.302)	Laziness (0.262)	Happiness (0.411)	Joy (0.306)	Thrill (0.214)
	Control	Fear (0.315)	Sadness (0.289)	Laziness (0.251)	Happiness (0.395)	Joy (0.298)	Thrill (0.205)
Geometry	Experimen	Square (0.456)	Triangle (0.413)	Area (0.396)	Angle (0.468)	Triangle (0.458)	Square (0.415)
	Control	Square (0.445)	Triangle (0.402)	Area (0.385)	Angle (0.455)	Triangle (0.447)	Square (0.405)
Trigonometry	Experimen	Triangle (0.605)	Geometry (0.264)	Number (0.249)	Triangle (0.495)	Cosine (0.482)	Sine (0.467)
	Control	Triangle (0.590)	Geometry (0.255)	Number (0.240)	Triangle (0.482)	Cosine (0.470)	Sine (0.455)

The findings of the study indicate significant changes in emotional expression, understanding of geometry, and comprehension of trigonometric concepts between the pre-test and post-test phases. In terms of emotional aspects, students in the experimental group initially displayed a predominance of negative emotions, such as fear (0.327), sadness (0.302), and laziness (0.262). However, following the intervention, there was a notable shift toward positive emotions, with happiness (0.411), joy (0.306), and thrill (0.214) emerging as the most dominant. A similar trend was observed in the control group, although the increase in positive emotions was less pronounced happiness (0.395), joy (0.298), and thrill (0.205). In the domain of geometry, the use of terminology in the experimental class shifted from basic to more complex concepts. During the pre-test, the most frequently mentioned terms were *square* (0.456), *triangle* (0.413), and *area* (0.396). After the intervention, the focus shifted to more abstract concepts, with *angle* (0.468) becoming the most dominant term, followed by *triangle* (0.458) and *square* (0.415). Although the control group exhibited a similar pattern, the magnitude of change was smaller (*angle* 0.455, *triangle* 0.447, *square* 0.405).

Regarding trigonometric concepts, the experimental group demonstrated a significant increase in the variety of terms used. In the pre-test, the majority of students mentioned only *triangle* (0.605), *geometry* (0.264), and *number* (0.249). After the intervention, there was a marked rise in the use of specific terminology, such as *cosine* (0.482) and *sine* (0.467), with *triangle* still dominant (0.495). Meanwhile, the control group also showed improvement but with lower values (*cosine* 0.470, *sine* 0.455, *triangle* 0.482), indicating a more substantial impact of the intervention on the experimental class. Overall, the intervention proved effective in enhancing student motivation, conceptual understanding, and the use of academic language in learning geometry and trigonometry. The impact was notably more significant in the experimental group than in the control group. Statistical analysis revealed that both intrinsic and extrinsic motivation scores from the MotLearn-Q questionnaire increased significantly from pre-test to post-test ($p < 0.05$), particularly within the experimental group (Table 9).

Accordingly, hypothesis H_3, which posits that gamification contributes to vocabulary expansion, especially in trigonometric terminology, was supported, with greater improvement observed in the experimental group compared to the control group. Thus, the null hypothesis (H_0) was rejected for the trigonometry category, confirming the effectiveness of gamification in expanding vocabulary in this area. Conversely, no significant difference was found in the geometry category, leading to the acceptance of H_0 for that domain.

Table 11

Statistical Analysis of Student Improvement

Variable	Category	Experimental (N = 45)	Z / χ² / F / t	p-value	Control (N = 44)	Z / χ² / F / t
Gender	Male (Δ +4.5%, p = 0.006)	12 students improved (54.5%)	Z = -2.98	0.003	10 students improved (50.0%)	Z = -2.75
	Female (Δ +8.7%, p = 0.005)	11 students improved (47.8%)	Z = -3.12	0.002	9 students improved (39.1%)	Z = -2.80
Academic Level (p =	High (Δ +20.0%, p = 0.008)	9 students improved (60.0%)	χ² = 7.82	0.005	6 students improved (40.0%)	χ² = 6.75
	Medium (Δ +6.7%, p = 0.015)	7 students improved (46.7%)	χ² = 6.42	0.011	6 students improved (40.0%)	χ² = 5.98
	Low (Δ +6.6%, p = 0.023)	5 students improved (33.3%)	χ² = 5.87	0.017	4 students improved (26.7%)	χ² = 5.20
Learning Style	Visual (Δ +14.2%, p = 0.012)	8 students improved (57.1%)	F(2,86) = 4.92	0.008	6 students improved (42.9%)	F(2,85) = 4.10
	Auditory (Δ +6.7%, P = 0.014)	7 students improved (46.7%)	F(2,86) = 4.67	0.009	6 students improved (40.0%)	F(2,85) = 4.05
	Kinesthetic (Δ +6.2%, P = 0.018)	6 students improved (37.5%)	F(2,86) = 4.23	0.013	5 students improved (31.3%)	F(2,85) = 3.89
Motivation Type	Intrinsic (Δ +14.3%, P = 0.004)	15 students improved (71.4%)	t(87) = -3.28	0.001	12 students improved (57.1%)	t(85) = -2.95
	Extrinsic (Δ +12.5%, p = 0.008)	13 students improved (54.2%)	t(87) = -2.97	0.003	10 students improved (41.7%)	t(85) = -2.65

The findings confirm that both intrinsic and extrinsic motivation scores significantly increased within the experimental group ($p < 0.05$), whereas the control group experienced a more modest improvement. The increase was particularly notable among students with intrinsic motivation (71.4% in the experimental group vs. 57.1% in the control group) and those with high academic achievement (60.0% vs. 40.0%). In terms of learning styles, visually oriented students showed the highest improvement (57.1% experimental vs. 42.9% control), suggesting that gamification is more effective for learners who rely on visual processing. Additionally, male students in the experimental group experienced a greater increase in motivation (54.5%) compared to female students (47.8%). Thus, as post-test motivation scores were significantly higher in the experimental class than in the control class,

hypothesis H_4 was accepted, confirming that gamification significantly enhances students' motivation in learning contexts.

The Relationship Between Academic Achievement and Global Motivation

Students' academic achievement was measured using two written tests: one administered prior to the geometry unit and the other following the completion of the unit, which incorporated a gamified learning approach. Both tests were scored on a scale from 1 to 7, in accordance with the school's grading criteria, which require a minimum proficiency level of 60% to achieve a passing grade of 4. To measure student motivation, the MotLearn-Q instrument was employed. Scores for various motivation categories were calculated by summing the values assigned to each response within the corresponding category. The analysis of results accounted for differences based on gender and age. Raw scores for global, intrinsic, and extrinsic motivation were subsequently converted into percentile scores to facilitate interpretation. These scores ranged from 0 to 100, with a value of 50 representing the average level of student motivation. Scores below 50 indicated low motivation, while scores above 50 signified high motivation. The conversion of raw scores to percentiles was conducted based on a scale aligned with students' academic level, learning style, gender, and type of motivation (intrinsic or extrinsic). To examine the relationship between the two variables in a small sample ($n \leq 50$), the Shapiro–Wilk normality test was applied. The results indicated that the academic achievement variable was normally distributed, with a significance level of 0.062 ($p > 0.05$). In contrast, the motivation variable was not normally distributed, with a significance level of 0.005 ($p < 0.05$). Descriptive statistics confirmed this distributional difference between the two quantitative variables. Given that one of the variables was not normally distributed, the correlation was analyzed using Spearman's non-parametric test. Table 7 presents the results of the correlation analysis between academic achievement and motivation in both the experimental and control groups during the pre-test and post-test stages.

Table 7

Correlation Between Academic Achievement and Motivation in Pre-Test and Post-Test (Experimental vs. Control Groups)

Group	Test	Variables	Spearman's ρ	Significance (p-value)
Experimental	Pre-Test	Academic Achievement → Motivation	0.472	0.038
	Pre-Test	Motivation → Academic Achievement	0.472	0.038
	Post-Test	Academic Achievement → Motivation	0.589	0.012
	Post-Test	Motivation → Academic Achievement	0.589	0.012
Control	Pre-Test	Academic Achievement → Motivation	0.298	0.102
	Pre-Test	Motivation → Academic Achievement	0.298	0.102
	Post-Test	Academic Achievement → Motivation	0.365	0.085
	Post-Test	Motivation → Academic Achievement	0.365	0.085

Spearman's correlation analysis revealed that in the experimental group, the relationship between motivation and academic achievement increased significantly from the pre-test ($\rho = 0.472$, $p = 0.038$) to the post-test ($\rho = 0.589$, $p = 0.012$). In contrast, the control group also showed an increase in correlation from $\rho = 0.298$ to $\rho = 0.365$; however, the correlation remained weak and statistically insignificant ($p > 0.05$). Consequently, Hypothesis H_5 was accepted, indicating that gamification not only enhances motivation and academic achievement individually but also strengthens the relationship between the two, making students more motivated to achieve better learning outcomes.

Discussion

Recent research indicates that the success of learning is not solely determined by cognitive abilities but is also significantly influenced by students' motivation to engage actively in the learning process (Forsblom et al., 2022; Tao et al., 2022). In this context, gamification the integration of game elements into educational activities has gained increasing attention for its ability to make learning more engaging and interactive (Jaramillo-Mediavilla et al., 2024; Ratinho & Martins, 2023). Gamification has been shown to enhance intrinsic motivation, which in turn fosters the development of critical thinking skills such as decision-making, problem-solving, and independent learning (Kaya & Ercag, 2023). Jaramillo-Mediavilla et al. (2024) emphasize that gamification design must align with curriculum objectives in order to actively encourage exploration of material and completion of challenging tasks. Their study further demonstrates that well-designed gamification strategies not only emotionally engage students but also significantly improve academic performance, including in mathematics. Forsblom et al. (2022) identified a connection between cognitive appraisal, achievement emotions, and mathematics learning outcomes, underlining the vital role of motivation in supporting academic success. Similarly, Wang et al. (2021) noted that students' engagement in learning mathematics is significantly influenced by metacognition, interest, and self-regulation. These findings reinforce the argument that student motivation can be enhanced through innovative approaches such as gamification, which fosters more enjoyable and meaningful learning experiences. Rasti-Behbahani and Shahbazi (2020) found that digital game-based tasks significantly improve vocabulary comprehension and mastery, suggesting the effectiveness of this approach across various learning contexts, including mathematics. Likewise, Papp (as cited in Vankúš, 2021) observed that students at various educational levels view gamification as an appealing strategy that does not require expensive technology to implement effectively.

In the context of mathematics, especially geometry, students often perceive the subject as difficult and overly reliant on memorization (Satsangi et al., 2019). However, Satsangi et al. also highlight that video modeling and gamification-based approaches help students with learning difficulties better understand contextual geometry problems. Geometry plays a crucial role in developing logical reasoning and spatial thinking; thus, its instruction should be designed to be interactive and application-oriented (Kaplar et al., 2022). As a practical application of this approach, the present study implemented an incentive- and reward-based gamification strategy to enhance student engagement. Results indicated a marked improvement in learning motivation following the gamified intervention. During the initial stage (pre-test), students frequently expressed negative emotions such as "fear," "laziness," and "boredom" toward mathematics. However, post-intervention, there was a notable shift toward positive emotions, including "happiness," "excitement," and "curiosity." These findings support those of Kaya and Ercag (2023), who concluded that gamification enhances emotional and motivational aspects of learning while also reshaping students' perceptions of subjects initially deemed difficult.

Gamification is an innovative educational approach that incorporates game elements into the learning environment to increase student engagement, strengthen teacher-student interaction, and enrich the overall learning experience. This approach contributes not only to increased motivation but also positively impacts students' academic performance (Ratinho & Martins, 2023; Zhang et al., 2021). It is important to distinguish between gamification and

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https://onlinelibrary.wiley.com/doi/10.1155/2024/5552365 game-based learning. Gamification refers to the integration of game elements such as points, levels, or challenges into non-game contexts to promote desired behaviors. In contrast, game-based learning involves the use of games explicitly as part of the instructional process (Jaramillo-Mediavilla et al., 2024; Vankúš, 2021). In the field of mathematics education, gamification has proven to positively influence both motivation and academic achievement. Through experimental research, Kaya and Ercag (2023) demonstrated that challenge-based gamification programs significantly improve learning outcomes, intrinsic motivation, and students' experience of flow. These findings align with those of Rasti-Behbahani and Shahbazi (2020), who reported that digital game-based tasks effectively enhance knowledge acquisition and student engagement.

Zhang et al. (2021) also support this perspective, revealing that gamification platforms such as Classcraft significantly boost academic achievement and learning motivation. Moreover, a systematic review by Ratinho and Martins (2023) found that gamification strategies greatly contribute to student motivation at both secondary and higher education levels. Additionally, Jaramillo-Mediavilla et al. (2024) assert that the incorporation of game elements into instruction not only drives student engagement but also has a direct effect on academic performance. Even with relatively minimal resource investment, gamified dashboards can yield significant outcomes in large-scale STEM education. Therefore, to design effective and meaningful mathematics instruction, educators are encouraged to adopt adaptive, technology-driven teaching strategies. Integrating gamification into the learning process not only enhances the appeal of mathematics instruction but also strengthens students' intrinsic motivation (Guay, 2021; Morris et al., 2022), ultimately leading to improved academic performance.

Conclusion

This study aimed to develop a gamification-based didactic module for teaching geometry in secondary schools to enhance student motivation. In addition, it investigated the correlation between motivation and academic achievement within a selected cohort, alongside other contributing variables. The geometry unit focused specifically on fundamental concepts of trigonometric ratios. To support the learning process, gamified activities were implemented, incorporating game mechanics, a reward-and-penalty system, and interactive elements. Each component was represented through emojis that students collected throughout the module, serving to maintain their motivation and engagement. Digital platforms such as PhET, Kahoot, and TikTok were also utilized to increase student participation in interactive learning.

The intervention results revealed improvements in students' motivation, engagement, responsibility, and self-confidence in understanding the material. Motivation levels were measured using the Motivation Evaluation Questionnaire in the Learning Process (MotLearn-Q), which indicated a significant increase in overall motivation. The post-test results supported the fourth research hypothesis, showing higher global motivation scores compared to the pre-test. A parametric t-test further confirmed a significant increase in academic performance, with average pre-test scores rising from 40.9 to 52.6 in the post-test. This difference highlights the effectiveness of gamification in enhancing learning outcomes.

Furthermore, the study analyzed the Lexical Availability Index (LAI) to explore the relationship between emotional vocabulary, motivation, and student engagement. This analysis assessed word dominance within the cognitive structure and the alignment between individual and group lexicons. The Spearman test confirmed a significant correlation between motivation and academic achievement, reinforcing the hypothesis that increased global motivation positively impacts academic performance. Overall, the findings affirm that gamification is an effective pedagogical strategy for improving mathematics learning in secondary education. Gamification functions as a motivational trigger, reducing stress from challenging academic tasks while alleviating boredom and other learning barriers. The integration of digital tools enabled students to develop more effective learning strategies, improve conceptual understanding, and achieve higher academic success.

Limitations and Directions for Future Research

Despite demonstrating that gamification positively influences motivation and academic achievement, several limitations should be acknowledged. First, although the observed effects were consistent among Grade 10 students, studies with larger sample sizes may yield more generalizable results. Additionally, since the sample was drawn from a single educational institution, the findings may not be fully applicable to broader populations. Future studies should involve students from diverse backgrounds and institutions, as cultural factors may influence the effectiveness of gamification. The inclusion of a control group would also help provide a clearer understanding of gamification's actual impact.

Moreover, the duration of the intervention in this study may have been too short to observe the long-term effects of gamification on motivation and academic achievement. Future research is encouraged to implement interventions over longer periods to yield more comprehensive results. Lastly, although this study focused on gamification as the primary factor influencing motivation and academic performance, other elements such as student characteristics, teacher effectiveness, and family support, also play a role. Future studies integrating these factors will provide a more holistic understanding of the multiple dimensions affecting student motivation and academic success.

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1 **Southeast Asia Mathematics Education Journal,** Volume 13, No 1 (2023)

Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement

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Abstract

This study investigated the impact of a gamification-based didactic program on students' motivation, lexical availability, and academic achievement in high school geometry. Addressing concerns over low student engagement and performance in mathematics, often due to abstract content and passive pedagogy, the research integrates gamified elements into ICT-based geometry modules to foster active and meaningful learning. Anchored in Self-Determination Theory and the ARCS Motivation Model, the study employed a quasi-experimental design with a pretest-posttest control group, involving 89 tenth-grade students students (aged 15–16), consisting of 45 females (50.6%) and 44 males (49.4%), from a from a subsidized private school in Jakarta. Over a five-week trigonometry unit, the experimental group engaged with digital tools including *PhET* simulations, *Kahoot!*, and *TikTok*-based mnemonic media, all structured within the e-TPACK framework. Results showed a 23% improvement in academic performance based on pre- and post-test comparisons. Gamification significantly enhanced students' verbal expression in geometry, as reflected in increased word production and lexical diversity. Post-test motivation scores were also higher in the experimental group, indicating greater engagement. Moreover, a stronger correlation between motivation and academic achievement in this group reinforces gamification as a robust pedagogical strategy for enhancing learning outcomes in secondary mathematics education. These findings suggest that educators and curriculum developers should consider systematically integrating gamified, ICT-supported modules anchored in motivational theories such as SDT and ARCS into geometry instruction. Future implementations should prioritize culturally relevant game elements and adaptive technologies to sustain engagement, particularly among diverse student populations.

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Keywords: Academic Achievement, Gamification, Geometry Education, Lexical Availability, Student Motivation.

Introduction

Mathematics education is often perceived by students as difficult, abstract, and unengaging (Yulianto et al., 2024; Forsblom et al., 2022; Bouchée et al., 2021). This perception contributes to increased levels of mathematics anxiety (Mamolo, 2022; Wang et al., 2020) and diminished student participation in classroom activities (Yulianto et al., 2024), ultimately leading to lower academic achievement (Wild, 2024; Dahri et al., 2024). According to the 2023 PISA results, many students struggle to comprehend abstract mathematical concepts and apply higher-order thinking skills (OECD, 2023), a condition further exacerbated by traditional teaching methods that are often passive and disconnected from real-life contexts (Yulianto et al., 2024). This situation underscores the urgent need for innovative, constructivist-based approaches that can activate student engagement and foster learning motivation.

Motivation plays a pivotal role in shaping students' engagement with mathematics, especially when the subject matter is perceived as abstract and challenging. According to Ryan and Deci (2020), intrinsic motivation can flourish when the basic psychological needs for autonomy, competence, and relatedness are fulfilled, as posited by Self-Determination Theory. In digital learning contexts, gamification offers structures that meet these needs through challenges, immediate feedback, and elements of competition (Guay, 2021; Kaya & Ercag, 2023). Importantly, gamification is not merely about playing games, but about integrating game elements into academic activities to stimulate cognitive exploration and foster a sense of achievement (Zeybek & Saygı, 2023). These mechanisms are consistent with Keller's ARCS model of motivational design, which emphasizes attention, relevance, confidence, and satisfaction as crucial for sustained engagement (Zhang et al., 2021; Fuentes-Riffo et al., 2023). Within geometry instruction, gamification not only increases motivation but also enhances lexical availability—the learner's ability to access and use mathematical vocabulary effectively (Shibata, 2021; Rasti-Behbahani & Shahbazi, 2020). Features such as timed challenges, adaptive repetition, and visual feedback enable students to develop deeper conceptual understanding of terms like "right angle," "reflection," or "axis of symmetry" (Shi, 2022; Satsangi et al., 2019). Thus, gamification emerges not only as a motivational tool but also as a pedagogical mechanism that deepens and contextualizes students' mathematical concept mastery.

One emerging and increasingly relevant pedagogical strategy is gamification, the incorporation of game elements into non-game contexts (Priyadi et al., 2023). Empirical studies have shown that gamification can enhance students' motivation, engagement, and learning outcomes (Zeybek & Saygı, 2023), particularly when grounded in robust motivational theories. Self-Determination Theory (Deci & Ryan, 2020) posits that game elements can enhance intrinsic motivation by fulfilling basic psychological needs for autonomy, competence, and relatedness. In parallel, the ARCS Model of Motivation (Yulianto et al., 2024) highlights the importance of incorporating challenge, reward, and competition to capture attention and build students' confidence. Nevertheless, the effectiveness of gamification remains a topic of scholarly debate. Some studies caution that poorly designed gamified environments may increase academic pressure or yield only short-term gains in engagement (Mamekova et al., 2021; Bai et al., 2020).

Among the various branches of mathematics, geometry is particularly well-suited for gamified instruction due to its reliance on spatial visualization skills, which can be effectively supported through simulations and interactive media (Schutera et al., 2021; Schoevers et al., 2020). Experimental studies have demonstrated that gamified geometry learning significantly boosts student motivation and academic performance (Fuentes-Riffo et al., 2023), while also enhancing spatial visualization through the use of virtual environments and 3D technologies (Herrera et al., 2024). However, most existing studies remain general in scope and have yet to examine the nuanced impacts of gamification within complex socio-pedagogical contexts, such as schools with limited resources or students with diverse learning styles. Therefore, this study aims to evaluate the impact of a gamified geometry learning unit on the motivation and academic performance of senior high school students at a subsidized private institution in Jakarta, Indonesia. Specifically, the study investigates whether gamification integrated through ICT platforms within the e-TPACK framework can foster intrinsic and extrinsic motivation, enrich lexical availability, and enhance academic achievement in trigonometric topics. To guide this investigation, the following research questions are formulated: (1) To what extent does the implementation of gamified geometry instruction influence students' academic achievement compared to conventional methods? (2) How does gamification affect students' motivation (intrinsic, extrinsic, and global) in the context of secondary mathematics learning?

(3) In what ways does gamified instruction impact students' lexical availability related to geometry and trigonometry concepts? (4) What is the relationship between students' motivation levels and their academic achievement in a gamified learning environment?

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Methods

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Type and Approach of the Study

This study employed a quantitative approach with a quasi-experimental pre-test–post-test control group design to evaluate the effectiveness of gamification in geometry learning on students' motivation and academic achievement. This design was selected as it allows for a comparative evaluation in real classroom settings without the need for ethically problematic random assignment. The research was conducted in 2024 among secondary school students in Jakarta, Indonesia, involving two groups: an experimental group (utilizing a gamification platform) and a control group (receiving conventional instruction). The instruments used were a geometry test and the Motivation in Learning Questionnaire (MotLearn-Q), administered before and after the intervention. The intervention was developed based on the ARCS motivational model and cognitive engagement theory, incorporating interactive elements and real-time feedback. Data were analyzed using t-tests and ANCOVA to assess the effectiveness of the intervention and examine the relationship between motivation and learning outcomes.

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Table 1

Quasi-Experimental One-Group Pre-Test Post-Test Design

Group	Pre-test	Intervensi Gamifikasi	Post-test
Experimental (E)	O_1	X	O_2
Control (C)	O_3	–	O_4

Participants and Sample Selection Criteria

This study involved 10th-grade students from a public secondary school in DKI Jakarta, comprising a total population of 89 students enrolled in a geometry course. The selection of this grade level was based on curricular relevance, as students at this stage begin to engage with critical spatial concepts such as trigonometric ratios and geometric reasoning, foundational elements for developing advanced mathematical visualization and thinking. Given the nationwide challenges in geometry achievement and low student engagement (OECD, 2023), this cohort was deemed strategically appropriate for a gamification-based intervention. Using stratified random sampling based on gender and academic achievement, 45 students were assigned to the experimental group and 44 to the control group. Baseline characteristics were balanced across groups to minimize potential bias. The school was selected for its adequate technological infrastructure and internal policies that support digital learning innovation. Inclusion criteria required active participation in geometry instruction and a minimum level of technological readiness. All participation was voluntary, with informed parental consent and official approval from the school administration.

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Table 2

Demographic Characteristics of the Participants

Variable	Category	n	%
Gender	Male	20	44.4%
	Female	25	55.6%
Academic Achievement Level	Low (< 60)	8	17.8%
	Medium (60–79)	21	46.7%
	High (≥ 80)	16	35.5%
Technology Access	Own personal device	37	82.2%
	School-provided device	6	13.3%
	Limited/borrowed device	2	4.5%
Frequency of Technology Use *(in Learning Activities)*	Never (< 1x/week)	3	6.7%
	Rarely (1–2x/week)	10	22.2%
	Often (3 – 4x /week)	20	44.4%
	Very often (≥ 5x/week)	12	26.7%
Prior Experience with Gamification	No experience	18	40.0%
	Has used gamification	27	60.0%
Learning Style	Visual	14	31.1%
	Auditory	9	20.0%
	Kinesthetic	12	26.7%
	Mixed (Visual – Auditory – Kinesthetic)	10	22.2%
Type of Motivation	Intrinsic	26	57.8%
	Extrinsic	19	42.2%

Assumption Testing for Pre-Test and Post-Test

To ensure the inferential validity of the research findings, prerequisite tests for ANCOVA were conducted, including assessments of normality and homogeneity of variances. The Shapiro–Wilk test indicated that the data were normally distributed across all groups ($p > 0.05$), while Levene's test confirmed the equality of variances ($p = 0.271$). Satisfying both assumptions ensures that the observed differences in post-test scores are significantly attributable to the gamification intervention, rather than to extraneous variables or pre-existing differences in participant characteristics. This approach aligns with the standard procedures for covariate analysis in technology-enhanced instructional media research (Field, 2013; Tabachnick & Fidell, 2019), thereby supporting the validity and generalizability of the results.

Table 3

Descriptive Statistics of Students' Pre-Test Scores

Variable	Category	n	Mean	SD	Shapiro–Wilk (p)	Levene's Test (p)
Gender	Male	44	67.8	8.5	0.078 (Normal)	0.293 (Homogeneous)
	Female	45	66.5	9.2	0.091 (Normal)	
Academic Level	High	30	75.4	6.8	0.061 (Normal)	0.256 (Homogeneous)
	Medium	30	68.1	7.9	0.089 (Normal)	
	Low	29	60.7	8.3	0.102 (Normal)	
Learning Style	Visual	28	69.5	7.8	0.073 (Normal)	0.317 (Homogeneous)
	Auditory	30	66.2	8.6	0.081 (Normal)	
	Kinesthetic	31	64.8	9.1	0.094 (Normal)	
Type of Motivation	Intrinsic	42	71.2	7.5	0.068 (Normal)	0.229 (Homogeneous)
	Extrinsic	47	63.9	8.9	0.084 (Normal)	

Instruments and Data Collection

Three primary instruments were employed complementarily to measure learning motivation, lexical availability, and conceptual understanding of geometry within the context of game-based instruction. The *Motivational Learning Process Questionnaire* (MotLearn-Q), cross-culturally adapted from Spain, demonstrated high internal reliability (α = 0.925) and consistent construct validity, although further localization is recommended for the Indonesian educational context (Beaton et al., 2000). The *Lexical Availability Test* was validated through both confirmatory and exploratory factor analyses (CFA: CFI = 0.91; RMSEA = 0.06), covering the categories of geometry, trigonometry, and emotions associated with geometry, thereby offering a novel contribution to the mapping of mathematics-related verbal skills. The *Geometry Test* was designed based on Bloom's evaluative framework to assess students' spatial and conceptual understanding in a gamified learning environment. The integration of these three instruments is intended to capture the cognitive, affective, and metalinguistic dimensions of learning, enabling a holistic assessment of the impact of game-based instruction.

Research Procedure

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To enhance clarity and facilitate replication, the instructional procedure is visually presented in the following flowchart. This flowchart outlines the five-week progression of the e-TPACK-based instructional design for the trigonometry unit, including learning objectives, tools, emotional targets, and expected cognitive processes (Figure 1). In this study, a sequence of instructional activities was designed to be implemented over five weeks within the trigonometry unit as part of the geometry curriculum. The instructional approach employed is based on the e-TPACK model, an extension of the Technological Pedagogical Content Knowledge (TPACK) framework. This model emphasizes the integration of Information and Communication Technology (ICT) in classroom instruction. The e-TPACK model incorporates key elements such as digital technologies, Bloom's Digital Taxonomy, and emotional engagement enhanced through gamification. Gamification is applied through a reward system intended to motivate students at each stage of learning. Moreover, this approach aligns learning activities with students' cognitive levels based on Bloom's Digital Taxonomy, thereby enabling learners to engage in progressively complex thinking from basic to higher-order skills. To ensure the model's effectiveness, this study systematically organizes instructional steps, as detailed in Table 4. The table outlines the stages of e-TPACK implementation in the teaching of trigonometry.

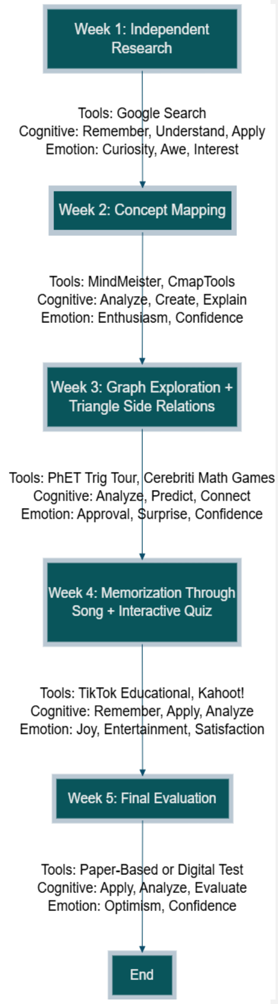
Table 4

Instructional Sequence of the e-TPACK Model

Activity	Bloom's Taxonomy	Technology	Emotions Evoked	Figure 1. Instructional Flow of e-TPACK-Based Trigonometry Module
Independent Research: Students search for information on trigonometric ratios and similarity. They gather materials, highlight	Remember, Understand, Apply	*Google*	Interest, Curiosity, Awe	

Activity	Bloom's Taxonomy	Technology	Emotions Evoked
key points, and summarize their findings in a notebook.			
Concept Mapping: Students create a concept map based on their research, then explain and compare their results with peers.	Analyze, Create, Connect, Explain	*MindMeister, Cmap Tools*	Enthusiasm, Confidence, and Interest
Graph Exploration: Students analyze graphs and angles in a circle, relate angles to trigonometric ratios (sin, cos, tan), and make conjectures about emerging patterns using an interactive simulator.	Analyze, Connect, Predict	*PhET Trig Tour*	Awe, Approval, Curiosity, Interest
Triangle Side Relations: Students identify relationships among the sides of right-angled triangles and apply trigonometric principles to form appropriate ratios.	Connect, Identify, Predict	*Cerebriti Math Games*	Confidence, Surprise, Curiosity
Memorization Through Song: Students memorize basic trigonometric values using songs on TikTok and apply them to solve problems.	Remember, Apply	*TikTok Educational*	Joy, Enthusiasm, Entertainment, Awe
Interactive Quiz: Students complete a Kahoot! quiz to assess their understanding. High scores earn bonus points in the assessment.	Recognize, Analyze, Identify	*Kahoot!*	Curiosity, Joy, and Confidence
Final Evaluation: Students take a test on trigonometric ratios and their applications in various problems.	Remember, Understand, Apply, Analyze, Evaluate	*Trigonometry Test*	Confidence, Optimism, Approval

Figure 1. Instructional Flow of e-TPACK-Based Trigonometry Module



The Gamification Approach in Geometry Learning

The gamification approach in geometry learning, as described in this text, involves three main strategies aimed at increasing student engagement: rewards, interactions, and penalties. Within the reward system, students earn emojis as a form of appreciation for their performance in completing learning activities. Interactions occur both among students as players and between students and the teacher acting as the adjudicator. These interactions foster social engagement and collaboration throughout the learning process. Meanwhile, the penalty system is implemented by deducting previously earned emojis when students commit predefined violations. At the end of the module, students can redeem their collected emojis for specific benefits, as outlined in Table 5. This approach differs significantly from traditional methods of teaching geometry, which tend to focus more on understanding trigonometry through calculations involving angles and distances using the Law of Sines and the Law of Cosines. In conventional methods, students are typically assigned exercises that emphasize the mechanical manipulation of mathematical formulas or rote learning, wherein they merely follow calculation steps without fully grasping the practical applications. As a result, for some students, such learning may feel abstract and less relevant to real-life contexts. In this regard, gamification emerges as a more engaging and effective solution by offering a learning experience that is interactive, meaningful, and motivational, encouraging students to develop a deeper understanding of geometric concepts, particularly in relation to fields such as physics, engineering, and astronomy.

Table 5

Benefits of Emojis Collected by Students

Number of Emojis Collected	Benefit
More than 15 emojis	Maximum bonus score (7.0) for the subject.
Between 10 and 14 emojis	Additional 5 points for any evaluation during the semester.
Between 5 and 9 emojis	Removal of the lowest score in process-based tests.
Between 1 and 4 emojis	Additional 2 points for unit assessments.

Results and Discussion

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RQ1: Does Gamification Improve Academic Achievement in Geometry?

The testing of the first hypothesis (H_1) revealed that the gamification intervention significantly enhanced students' academic achievement, as evidenced by the results of a paired-samples t-test ($p < 0.001$) with a large effect size ($d = 1.141$), indicating a substantial practical impact according to Cohen's classification (see Table 6). This finding aligns with the results of Akman and Çakır (2020), who emphasized the role of gamification in reinforcing students' cognitive engagement and intrinsic motivation. Nevertheless, caution should be exercised in generalizing these results due to limitations related to the local cultural context and sample size. Further studies are recommended to examine the gamification model in diverse educational settings to ensure replication and external validity.

Table 6

Results of Paired-Samples t-Test for Academic Achievement

Group	Comparison	M	SD	MSE	CI	t	df	Sig.	Cohen's d
Experiment Class	Pre-test vs. Post-test	-11.572	6.630	0.988	[-13.636, -9.652]	-11.781	44	0.000	1.141
Control Class	Pre-test vs. Post-test	-10.851	6.400	0.956	[-12.950, -8.750]	-11.230	43	0.000	1.082

RQ2: Does Gamification Enhance Word Production in Geometry Explanations?

The second hypothesis (H_2) examines whether gamification can enhance students' word production in geometry explanations, as measured by comparing the number of words generated by the experimental and control groups in the post-test. The Lexical Availability Index (LAI) and the Proportional LAI (LAIp) were employed to assess students' lexical accessibility across the domains of emotion, geometry, and trigonometry, in accordance with educational linguistic analysis standards (Salcedo-Lagos et al., 2021). Although these instruments have been utilized in prior lexical studies, there is insufficient evidence to confirm that LAI directly reflects conceptual understanding in geometry, thereby necessitating further clarification of the supporting theoretical framework. The data were analyzed using either t-tests or Wilcoxon tests, depending on the normality of distribution; however, potential biases arising from non-instructional factors, such as students' intrinsic motivation, were not adequately controlled. Thus, the implications regarding the effectiveness of gamification must be more clearly delineated to align with the study's original objective: reinforcing students' conceptual-verbal competence in geometry. Table 7 results indicate a significant enhancement in lexical enrichment within the trigonometry domain ($p = 0.000$), while no meaningful differences were observed in the emotion and geometry domains ($p > 0.05$). These findings underscore that context-based instructional strategies are more effective in fostering the acquisition of domain-specific terminology in trigonometry compared to purely affective or geometric domains. This disparity may be attributed to the limited use of visual and affective stimuli in the instructional treatment, which did not fully incorporate students' cultural or emotional dimensions into geometry-related activities. These results suggest the need for the future development of more immersive and experiential learning designs for non-trigonometric domains.

Table 7

Lexical Availability Test Results and Statistical Analysis

Area of Interest	$\bar{x} \pm$ SD (Experiment)	$\bar{x} \pm$ SD (Control)	W	p-value (Normality)	Statistical Test	p-value
Emotion & Geometry	12.4 ± 3.1	12.2 ± 3.0	0.967	0.067 (normal)	t-test	0.215
Geometry	15.8 ± 4.2	15.5 ± 3.6	0.972	0.082 (normal)	t-test	0.089
Trigonometry	9.6 ± 2.8	5.81 ± 2.5	0.891	0.013 (not normal)	Wilcoxon test	0.000

The analysis presented in Table 8 indicates a significant increase in the use of trigonometric lexical terms in the experimental group ($\Delta M = +5.14$; $p < 0.001$), while the control group exhibited no meaningful change ($\Delta M = +0.06$; $p = 0.834$). These findings support the second hypothesis, suggesting that interventions employing trigonometry-specific media effectively enhance conceptual mastery of domain-specific terminology. No significant differences were observed in the emotion and geometry categories ($p > 0.05$), which may be attributed to the limited integration of affective and spatial components in the instructional design, as theorized in immersive learning frameworks (Makransky & Petersen, 2021). Thus, the results underscore the importance of content-specific emphasis in instructional media to improve terminological literacy within a given domain, while also highlighting potential limitations in addressing cross-domain constructs such as emotional engagement and geometric reasoning.

Table 8

Words Produced in Each Centre of Interest

Category	Group	Pre-test (N, M, SD)	Post-test (N, M, SD)	ΔM	p-value
Emotion	Experimental	244 (5.42, 1.21)	211 (4.68, 1.15)	-0.74	0.084
	Control	240 (5.40, 1.18)	238 (5.38, 1.17)	-0.02	0.915
Geometry	Experimental	557 (12.37, 2.54)	524 (11.64, 2.48)	-0.73	0.076
	Control	550 (12.40, 2.50)	545 (12.35, 2.49)	-0.05	0.967
Trigonometry	Experimental	255 (5.79, 1.32)	492 (10.93, 1.75)	+5.14	0.000
	Control	250 (5.75, 1.30)	258 (5.81, 1.33)	+0.06	0.834

RQ3: Does Gamification Expand Students' Geometry and Trigonometry Vocabulary?

The Lexical Availability Index (LAI) was employed to analyze lexical changes across three main categories: emotions related to geometry, geometric terminology, and trigonometric terminology. The results indicate that the intervention had varying impacts across these categories.

1. Emotions Related to Geometry.
   In the experimental group, there was a significant shift from negative to positive lexical items following the intervention. Prior to the intervention, the most dominant words were *fear* (32.7%), *sadness* (30.2%), and *laziness* (26.2%). After the intervention, these words showed a marked decrease, accompanied by a notable increase in positive lexical items such as *happiness* (41.1%), *joy* (30.6%), and *thrill* (21.4%). In contrast, the control group exhibited no statistically significant change ($p > 0.05$). Negative words remained predominant, including *fear* (31.5%), *sadness* (28.9%), and *laziness* (25.1%), while the increase in positive terms such as *happiness* (39.5%), *joy* (29.8%), and *thrill* (20.5%) did not represent a meaningful difference.
2. Geometric Terminology.
   In the category of geometric terminology, neither the experimental nor the control group demonstrated significant changes ($p > 0.05$). In the experimental group, there was a slight increase in the frequency of geometric terms. In the pre-test, the most frequently mentioned words were *square* (45.6%), *triangle* (41.3%), and *area* (39.6%). After the intervention, minor shifts were observed, with *angle* (46.8%), *triangle* (45.8%), and *square* (41.5%) becoming more prominent. In the control group, changes were minimal. The dominant terms remained *square* (44.5%), *triangle* (40.2%), and *area* (38.5%) in the pre-test, and *angle* (45.5%), *triangle* (44.7%), and *square* (40.5%) in the post-test. These results suggest that the intervention had no substantial effect on students' geometric terminology.
3. Trigonometric Terminology.
   In the category of trigonometric terminology, the experimental group demonstrated a significant increase in the number of terms ($p = 0.000$). The most dominant words in the pre-test were *triangle* (60.5%), *geometry* (26.4%), and *number* (24.9%). After the intervention, there was a noticeable shift, with a significant increase in the terms *triangle* (49.5%), *cosine* (48.2%), and *sine* (46.7%). In contrast, the control group did not show any significant change ($p > 0.05$), with the dominant pre-test terms remaining *triangle* (59.0%), *geometry* (25.5%), and *number* (24.0%). The post-test revealed only minimal changes, with *triangle* (48.2%), *cosine* (47.0%), and *sine* (45.5%) being the most common.

To test hypothesis H_3, a statistical analysis was conducted by comparing the mean differences in the Lexical Availability Index (LAI) before and after the intervention between the experimental and control groups. An independent t-test analysis revealed that gamification significantly improved the LAI in the trigonometric category ($t(87) = 3.28$, $p = 0.0015$), with a greater increase observed in the experimental group (ΔMean = 0.109) compared to the control group (ΔMean = 0.044, Cohen's $d = 0.695$). Conversely, in the geometry category, no significant difference was found ($t(87) = 0.59$, $p = 0.555$), suggesting that gamification had a stronger impact on expanding trigonometric vocabulary than geometric terminology.

Table 9

Independent T-Test Analysis for Trigonometry and Geometry Categories

Category	Group	ΔMean (Post - Pre)	SD Post	n	t-value	p-value	Cohen's d
Trigonometry	Experimental	0.109	0.095	45	3.28	0.0015	0.695
	Control	0.044	0.092	44			
Geometry	Experimental	0.023	0.098	45	0.59	0.555	0.126
	Control	0.011	0.093	44			

As shown in Table 9, gamification significantly increased the Lexical Availability Index (LAI) for the trigonometry category ($t(87) = 3.28$, $p = 0.0015$), with a greater improvement in the experimental group (ΔMean = 0.109) than in the control group (ΔMean = 0.044, d = 0.695). In contrast, no significant difference was found in the geometry category ($t(87) = 0.59$, $p = 0.555$), underscoring the stronger effectiveness of gamification in enhancing trigonometric vocabulary. Table 10 below presents the top three most available words in each of the three main categories: emotion, geometric terminology, and trigonometric terminology, based on the pre-test and post-test results.

Table 10

Top Three Most Available Words by Category of Interest

Category	Group	Pre-Test (LAI)			Post-Test (LAI)		
		Word 1	Word 2	Word 3	Word 1	Word 2	Word 3
Emotion	Experimen	Fear (0.327)	Sadness (0.302)	Laziness (0.262)	Happiness (0.411)	Joy (0.306)	Thrill (0.214)
	Control	Fear (0.315)	Sadness (0.289)	Laziness (0.251)	Happiness (0.395)	Joy (0.298)	Thrill (0.205)
Geometry	Experimen	Square (0.456)	Triangle (0.413)	Area (0.396)	Angle (0.468)	Triangle (0.458)	Square (0.415)
	Control	Square (0.445)	Triangle (0.402)	Area (0.385)	Angle (0.455)	Triangle (0.447)	Square (0.405)
Trigonometry	Experimen	Triangle (0.605)	Geometry (0.264)	Number (0.249)	Triangle (0.495)	Cosine (0.482)	Sine (0.467)
	Control	Triangle (0.590)	Geometry (0.255)	Number (0.240)	Triangle (0.482)	Cosine (0.470)	Sine (0.455)

The findings of this study reveal a significant shift in emotional expression, geometric understanding, and mastery of trigonometric concepts between the pre-test and post-test phases. In the affective domain, students in the experimental group transitioned from predominantly negative emotions (e.g., fear, sadness, apathy) to more positive ones (e.g., happiness, enthusiasm, interest), underscoring the crucial role of gamification in fostering constructive emotional engagement in mathematics learning, consistent with the findings of Makransky and Petersen (2021). In the geometry domain, there was a noticeable shift from the use of basic terms (e.g., *square*, *triangle*) to more abstract concepts (e.g., *angle*), reflecting an improvement in students' spatial cognitive representation, as supported by Akman and Çakır (2020). In trigonometry, the significant increase in the frequency of terms such as *sine* and *cosine* indicates the success of the intervention in internalizing core concepts that were previously underrepresented. These gains were not as pronounced in the control group, highlighting the advantages of VR-based gamification in promoting elaboration of mathematical terminology. Statistical analyses support these outcomes ($p < 0.05$), particularly in terms of intrinsic and extrinsic motivation, reinforcing the argument that this instructional innovation is effective not only cognitively but also affectively (see Table 11). However, the absence of significant differences in the geometry domain suggests a need to strengthen local cultural narratives to enhance the transfer of abstract spatial concepts, as recommended by Uteuliev and Madyarov (2022).

Table 11

Statistical Analysis of Student Improvement

Variable	Category	Experimental (N = 45)	Z / χ^2 / F / t	p-value	Control (N = 44)	Z / χ^2 / F / t
Gender	Male (Δ +4.5%, p = 0.006)	12 students improved (54.5%)	Z = -2.98	0.003	10 students improved (50.0%)	Z = -2.75
	Female (Δ +8.7%, p = 0.005)	11 students improved (47.8%)	Z = -3.12	0.002	9 students improved (39.1%)	Z = -2.80
Academic Level (p =	High (Δ +20.0%, p = 0.008)	9 students improved (60.0%)	χ^2 = 7.82	0.005	6 students improved (40.0%)	χ^2 = 6.75
	Medium (Δ +6.7%, p = 0.015)	7 students improved (46.7%)	χ^2 = 6.42	0.011	6 students improved (40.0%)	χ^2 = 5.98
	Low (Δ +6.6%, p = 0.023)	5 students improved (33.3%)	χ^2 = 5.87	0.017	4 students improved (26.7%)	χ^2 = 5.20
Learning Style	Visual (Δ +14.2%, p = 0.012)	8 students improved (57.1%)	F(2,86) = 4.92	0.008	6 students improved (42.9%)	F(2,85) = 4.10
	Auditory (Δ +6.7%, P = 0.014)	7 students improved (46.7%)	F(2,86) = 4.67	0.009	6 students improved (40.0%)	F(2,85) = 4.05
	Kinesthetic (Δ +6.2%, P = 0.018)	6 students improved (37.5%)	F(2,86) = 4.23	0.013	5 students improved (31.3%)	F(2,85) = 3.89
Motivation Type	Intrinsic (Δ +14.3%, P = 0.004)	15 students improved (71.4%)	t(87) = -3.28	0.001	12 students improved (57.1%)	t(85) = -2.95
	Extrinsic (Δ +12.5%, p = 0.008)	13 students improved (54.2%)	t(87) = -2.97	0.003	10 students improved (41.7%)	t(85) = -2.65

RQ4: Does Gamification Enhance Student Motivation in Mathematics Learning?

The findings confirm that both intrinsic and extrinsic motivation scores significantly increased within the experimental group ($p < 0.05$), whereas the control group experienced a more modest improvement. The increase was particularly notable among students with intrinsic motivation (71.4% in the experimental group vs. 57.1% in the control group) and those with high academic achievement (60.0% vs. 40.0%). In terms of learning styles, visually oriented students showed the highest improvement (57.1% experimental vs. 42.9% control), suggesting that gamification is more effective for learners who rely on visual processing. Additionally, male students in the experimental group experienced a greater increase in motivation (54.5%) compared to female students (47.8%). Thus, as post-test motivation scores were significantly higher in the experimental class than in the control class,

hypothesis H_4 was accepted, confirming that gamification significantly enhances students' motivation in learning contexts.

RQ5: What is the Relationship Between Motivation and Academic Achievement in Gamified Learning?

Academic achievement was measured using two written tests administered before and after the geometry unit, each scored on a 1–7 scale following the school's passing criteria (60%). Student motivation was assessed using the validated MotLearn-Q instrument (Deci & Ryan, 2000), which captures both intrinsic and extrinsic motivational constructs. Raw scores were converted into percentiles (ranging from 0 to 100) to facilitate interpretation, with a cutoff score of 50 representing the average level. The Shapiro–Wilk test confirmed a normal distribution for academic performance ($p > 0.05$), but not for motivation ($p < 0.05$), leading to the use of Spearman's rho for correlation analysis. As shown in Table 12, a significant increase was observed in the motivation–achievement correlation within the experimental group (ρ rose from 0.472 to 0.589; $p < 0.05$), aligning with Self-Determination Theory (Ryan & Deci, 2020), which posits that gamification can enhance the link between learning drive and academic outcomes. In contrast, the control group exhibited a weak and statistically insignificant relationship. These findings suggest that gamification influences not only individual learning components but also strengthens the synergy between students' motivation and academic performance.

Table 12

Correlation Between Academic Achievement and Motivation in Pre-Test and Post-Test (Experimental vs. Control Groups)

Group	Test	Variables	Spearman's ρ	Significance (p-value)
Experimental	Pre-Test	Academic Achievement → Motivation	0.472	0.038
	Pre-Test	Motivation → Academic Achievement	0.472	0.038
	Post-Test	Academic Achievement → Motivation	0.589	0.012
	Post-Test	Motivation → Academic Achievement	0.589	0.012
Control	Pre-Test	Academic Achievement → Motivation	0.298	0.102
	Pre-Test	Motivation → Academic Achievement	0.298	0.102
	Post-Test	Academic Achievement → Motivation	0.365	0.085
	Post-Test	Motivation → Academic Achievement	0.365	0.085

Discussion

Recent research indicates that the success of learning is not solely determined by cognitive abilities but is also significantly influenced by students' motivation to engage actively in the learning process (Forsblom et al., 2022; Tao et al., 2022). In this context, gamification the integration of game elements into educational activities, has gained increasing attention for its ability to make learning more engaging and interactive (Jaramillo-Mediavilla et al., 2024; Ratinho & Martins, 2023). Gamification has been shown to enhance intrinsic motivation, which in turn fosters the development of critical thinking skills such as decision-making, problem-solving, and independent learning (Kaya & Ercag, 2023). This is in line with epistemic-based learning models that emphasize structured problem-solving and representational fluency as critical aspects of meaningful mathematical engagement, particularly in geometry (Sridana et al., 2023; Isnawan et al., 2023). Jaramillo-Mediavilla et al. (2024) emphasize that gamification design must align with curriculum objectives in order to actively encourage exploration of material and completion of challenging tasks. Their study further demonstrates that well-

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designed gamification strategies not only emotionally engage students but also significantly improve academic performance, including in mathematics. Forsblom et al. (2022) identified a connection between cognitive appraisal, achievement emotions, and mathematics learning outcomes, underlining the vital role of motivation in supporting academic success. Similarly, Wang et al. (2021) noted that students' engagement in learning mathematics is significantly influenced by metacognition, interest, and self-regulation. These findings reinforce the argument that student motivation can be enhanced through innovative approaches such as gamification, which fosters more enjoyable and meaningful learning experiences. Rasti-Behbahani and Shahbazi (2020) found that digital game-based tasks significantly improve vocabulary comprehension and mastery, suggesting the effectiveness of this approach across various learning contexts, including mathematics. Likewise, Papp (Vankúš, 2021) observed that students at various educational levels view gamification as an appealing strategy that does not require expensive technology to implement effectively.

In the context of mathematics, especially geometry, students often perceive the subject as difficult and overly reliant on memorization (Satsangi et al., 2019). However, Satsangi et al. also highlight that video modeling and gamification-based approaches help students with learning difficulties better understand contextual geometry problems. Geometry plays a crucial role in developing logical reasoning and spatial thinking; thus, its instruction should be designed to be interactive and application-oriented (Kaplar et al., 2022; Kuncoro et al., 2021). This is further supported by research on hybrid didactical design and problem-based tasks, which demonstrate improved representational competence and conceptual understanding among students (Isnawan et al., 2023; Sukarma et al., 2023). As a practical application of this approach, the present study implemented an incentive- and reward-based gamification strategy to enhance student engagement. Results indicated a marked improvement in learning motivation following the gamified intervention. During the initial stage (pre-test), students frequently expressed negative emotions such as "fear," "laziness," and "boredom" toward mathematics. However, post-intervention, there was a notable shift toward positive emotions, including "happiness," "excitement," and "curiosity." These findings support those of Kaya and Ercag (2023), who concluded that gamification enhances emotional and motivational aspects of learning while also reshaping students' perceptions of subjects initially deemed difficult. This aligns with Jafaruddin and Chen (2023), who emphasized the importance of contextual and culturally responsive approaches, such as ethnomathematics and hypnoteaching in facilitating student engagement with geometry concepts in digital environments.

Gamification is an innovative educational approach that incorporates game elements into the learning environment to increase student engagement, strengthen teacher-student interaction, and enrich the overall learning experience. This approach contributes not only to increased motivation but also positively impacts students' academic performance (Ratinho & Martins, 2023; Zhang et al., 2021). It is important to distinguish between gamification and game-based learning. Gamification refers to the integration of game elements such as points, levels, or challenges into non-game contexts to promote desired behaviors. In contrast, game-based learning involves the use of games explicitly as part of the instructional process (Jaramillo-Mediavilla et al., 2024; Vankúš, 2021). In the field of mathematics education, gamification has proven to positively influence both motivation and academic achievement. Through experimental research, Kaya and Ercag (2023) demonstrated that challenge-based gamification programs significantly improve learning outcomes, intrinsic motivation, and students' experience of flow. These findings align with those of Rasti-Behbahani and Shahbazi (2020), who reported that digital game-based tasks effectively enhance knowledge acquisition and student engagement.

Zhang et al. (2021) also support this perspective, revealing that gamification platforms such as Classcraft significantly boost academic achievement and learning motivation. Moreover, a systematic review by Ratinho and Martins (2023) found that gamification strategies greatly contribute to student motivation at both secondary and higher education levels. Additionally, Jaramillo-Mediavilla et al. (2024) assert that the incorporation of game elements into instruction not only drives student engagement but also has a direct effect on academic performance. Even with relatively minimal resource investment, gamified dashboards can yield significant outcomes in large-scale STEM education. Therefore, to design effective and meaningful mathematics instruction, educators are encouraged to adopt adaptive, technology-driven teaching strategies. Integrating gamification into the learning process not only enhances the appeal of mathematics instruction but also strengthens students' intrinsic motivation (Guay, 2021; Morris et al., 2022), ultimately leading to improved academic performance. This is consistent with Kin (2015), who underscored the role of technology-enhanced learning in transforming mathematics education toward more engaging and effective practices.

Conclusion

This study aimed to develop a gamification-based didactic module for teaching geometry in secondary schools to enhance student motivation. In addition, it investigated the correlation between motivation and academic achievement within a selected cohort, alongside other contributing variables. The geometry unit focused specifically on fundamental concepts of trigonometric ratios. To support the learning process, gamified activities were implemented, incorporating game mechanics, a reward-and-penalty system, and interactive elements. Each component was represented through emojis that students collected throughout the module, serving to maintain their motivation and engagement. Digital platforms such as PhET, Kahoot, and TikTok were also utilized to increase student participation in interactive learning.

The intervention results revealed improvements in students' motivation, engagement, responsibility, and self-confidence in understanding the material. Motivation levels were measured using the Motivation Evaluation Questionnaire in the Learning Process (MotLearn-Q), which indicated a significant increase in overall motivation. The post-test results supported the fourth research hypothesis, showing higher global motivation scores compared to the pre-test. A parametric t-test further confirmed a significant increase in academic performance, with average pre-test scores rising from 40.9 to 52.6 in the post-test. This difference highlights the effectiveness of gamification in enhancing learning outcomes.

Furthermore, the study analyzed the Lexical Availability Index (LAI) to explore the relationship between emotional vocabulary, motivation, and student engagement. This analysis assessed word dominance within the cognitive structure and the alignment between individual and group lexicons. The Spearman test confirmed a significant correlation between motivation and academic achievement, reinforcing the hypothesis that increased global motivation positively impacts academic performance. Overall, the findings affirm that gamification is an effective pedagogical strategy for improving mathematics learning in secondary education. Gamification functions as a motivational trigger, reducing stress from challenging academic tasks while alleviating boredom and other learning barriers. The integration of digital tools enabled students to develop more effective learning strategies, improve conceptual understanding, and achieve higher academic success. Such improvement is congruent with studies that emphasize the importance of problem-solving-based epistemic learning and representational scaffolding in promoting mathematical meaning-making and abstraction, particularly in geometry (Sridana et al., 2023; Isnawan et al., 2023; Sukarma et al., 2023).

Limitations and Directions for Future Research

Despite demonstrating that gamification positively influences motivation and academic achievement, several limitations should be acknowledged. First, although the observed effects were consistent among Grade 10 students, studies with larger sample sizes may yield more generalizable results. Additionally, since the sample was drawn from a single educational institution, the findings may not be fully applicable to broader populations. Future studies should involve students from diverse backgrounds and institutions, as cultural factors may influence the effectiveness of gamification. The inclusion of a control group would also help provide a clearer understanding of gamification's actual impact.

Moreover, the duration of the intervention in this study may have been too short to observe the long-term effects of gamification on motivation and academic achievement. Future research is encouraged to implement interventions over longer periods to yield more comprehensive results. Lastly, although this study focused on gamification as the primary factor influencing motivation and academic performance, other elements such as student characteristics, teacher effectiveness, and family support also play a role. Future studies integrating these factors will provide a more holistic understanding of the multiple dimensions affecting student motivation and academic success.

Acknowledgements

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Rebuttal Table

Southeast Asian Mathematics Education Journal (SEAMEJ)

SEAMEO Regional Centre for QITEP in Mathematics

No	Content	Page	Requested Changes (Review/Feedback)	Description of Resulting Changes (Revision)	Page
1	General		The manuscript should be between **8 to 25 pages long (3000-9000 words)** included References. The reviewer suggested to revise the manuscript into up to 8000 words.	The manuscript has been revised and streamlined into approximately 7799 words while maintaining the depth and rigor of analysis according to the reviewer's recommendation.	Full manuscript
2	Abstract		Please see reviewer comment in the attached document	Abstract has been revised to sharpen the research gap, highlight the novelty of integrating gamification, lexical availability, and motivation, and clarify theoretical and empirical contributions.	1
3	Introduction		Provide the research question	Four clear research questions have been explicitly stated in the introduction section (RQ1-RQ4), addressing achievement, motivation, lexical availability, and correlation.	3
4	Method		Please see reviewer comment in the attached document	The methods section has been revised to clarify the research design (quasi-experimental) and flowchart.	3
5	Research Procedure		Provide a flowchart of the research procedure	The research procedure has been visualized into a flowchart outlining the 5-week gamification intervention sequence aligned with the e-TPACK model.	6
6	Result and discussion		Add sub-titles according to your research questions.	Subsections based on each research question (RQ1-RQ4) have been added to the Results and Discussion section to improve clarity and organization.	7
7	Discussion		The reviewer provides an additional article to be cited in the discussion section. Please see reviewer comment in the attached document.	Additional citations from recent SEAMEJ articles (e.g. Sridana et al., 2025; Isnawan et al., 2024; Sukarma et al., 2024) have been incorporated to strengthen the theoretical framework.	12
8	References		The reviewer suggested to add and cite at least three articles in **Southeast Asian Mathematics Education Journal**	Three relevant SEAMEJ articles (Jafaruddin & Chen, 2023; Isnawan et al., 2023; Kin, L., 2015) have been cited and included in the reference list.	16

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by Susilawati25512@gmail.com 1

Innovative Approaches to Geometry Learning: Harnessing Gamification and ICT to Elevate Student Motivation and Academic Achievement

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Abstract

This study investigates the impact of a gamification-based didactic program on students' motivation, lexical availability, and academic achievement in high school geometry. Addressing concerns over low student engagement and performance in mathematics often due to abstract content and passive pedagogy the research integrates gamified elements into ICT-based geometry modules to foster active and meaningful learning. Anchored in Self-Determination Theory and the ARCS Motivation Model, the study employed a quasi-experimental design with a pretest-posttest control group, involving 89 tenth-grade students from a subsidized private school in Jakarta. Over a five-week trigonometry unit, the experimental group engaged with digital tools including PhET simulations, Kahoot!, and TikTok-based mnemonic media, all structured within the e-TPACK framework. Results showed a 23% improvement in academic performance based on pre- and post-test comparisons. Gamification significantly enhanced students' verbal expression in geometry, as reflected in increased word production and lexical diversity. Post-test motivation scores were also higher in the experimental group, indicating greater engagement. Moreover, a stronger correlation between motivation and academic achievement in this group reinforces gamification as a robust pedagogical strategy.

Keywords: Academic Achievement, Gamification, Geometry Education, Lexical Availability, Student Motivation.

Introduction

Mathematics is often perceived by students as difficult, abstract, and uninteresting (Yulianto et al., 2024; Forsblom et al., 2022; Bouchée et al., 2021). This perception contributes to heightened levels of mathematics anxiety (Mamolo, 2022; Wang et al., 2020) and low engagement in learning activities (Yulianto et al., 2024; Wang et al., 2020). PISA results indicate that many students struggle to grasp abstract concepts and to apply higher-order thinking skills in mathematics (OECD, 2023). This issue is further exacerbated by traditional teaching methods, which tend to be passive, discourage conceptual exploration, and lack meaningful interaction between students and learning materials (Yulianto et al., 2024). As a result, students' motivation to learn declines, leading to poor academic achievement (Wild, 2024; Dahri et al., 2024; Cao, 2023).

To address this challenge, an innovative constructivist-based approach is needed one that encourages active student participation. One increasingly adopted method in education is gamification, which refers to the use of game elements in non-game contexts (Priyadi et al., 2023). Gamification has been shown to have a positive impact on student engagement, motivation, and academic achievement across various subjects, including mathematics (Zeybek & Saygı, 2023). This concept is grounded in Self-Determination Theory (Deci & Ryan, 2020), which posits that game elements can enhance intrinsic motivation by fulfilling the psychological needs for autonomy, competence, and relatedness. Additionally, the ARCS Model of Motivation (Yulianto et al., 2024) suggests that the inclusion of challenges, rewards, and competition in gamified environments can enhance students' attention, relevance, confidence, and satisfaction in learning. While numerous studies have indicated that gamification can improve student motivation and comprehension, its overall effectiveness remains a topic of debate (Zeng et al., 2024; Mamekova et al., 2021; Bai et al., 2020). Some research has found that, if not properly designed, gamification may increase academic pressure, diminish intrinsic motivation, or yield only short-term effects on student engagement (Mamekova et al., 2021; Bai et al., 2020). Therefore, further research is necessary to better understand how optimally designed gamification strategies can provide sustainable benefits in mathematics education.

One of the most promising branches of mathematics for integration with gamification is geometry, as it involves spatial understanding and visualization skills that can be enhanced through games and visual simulations (Schutera et al., 2021; Schoevers et al., 2020). Gamified geometry instruction has the potential to improve students' spatial thinking, problem-solving abilities, and geometric analysis. In secondary school geometry classrooms, the use of gamification has been shown to increase student motivation and academic achievement by 23% (Fuentes-Riffo et al., 2023). The incorporation of spatial visualization tools, such as virtual environments and 3D printing, has led to a 25% improvement in spatial visualization skills among experimental groups (Herrera et al., 2024). However, there remains a gap in the literature regarding the effects of gamified learning on student motivation and academic performance, particularly within educational systems characterized by diverse social, economic, and pedagogical contexts. Most existing studies examine gamification in mathematics education more broadly, with limited research specifically addressing how gamification enhances geometry comprehension or how contextual factors such as students' learning style backgrounds and teaching methods influence learning outcomes. Therefore, this study aims to evaluate the impact of a gamified geometry learning unit on the motivation and academic performance of senior high school students at a subsidized private institution in Jakarta, Indonesia.

Theoretical Support

Motivation

Motivation drives individuals to achieve goals through initiative, perseverance, and action (Gagné & Hewett, 2025; Cheng, 2023; Holding et al., 2021). Deci and Ryan (2020) emphasize the role of motivation in fostering learning engagement and resilience. Motivation is generally categorized into two types: intrinsic, which arises from personal interest, and extrinsic, which is influenced by external factors such as rewards. Extrinsic motivation depends on outcomes that are separate from the activity itself (Morris et al., 2022; Guay, 2021). In the context of mathematics education, motivation is shaped by task design, content relevance, peer interaction, assessment practices, teacher feedback, and instructional materials (Aust et al., 2024; Alipour et al., 2023; Kaplar et al., 2022; Cevikbas & Kaiser, 2021). It encompasses both interest and persistence in academic tasks (Gagné & Hewett, 2025; Cheng, 2023; Holding et al., 2021).

Gamification has been shown to enhance motivation by creating more enjoyable learning experiences through elements such as points, badges, and leaderboards which, in turn, can improve student motivation and academic achievement (Jaramillo-Mediavilla et al., 2024; Ratinho & Martins, 2023). Zhang et al. (2021) found that digital tools support the development of positive attitudes toward mathematics. Additionally, emotional factors, self-perceptions, and success expectations play significant roles in student engagement (Tao et al., 2022; Wang et al., 2021). Negative attitudes toward mathematics are often rooted in past negative experiences, stereotypes, and perceptions of difficulty (Woitzel & Alves, 2024; McKenzie et al., 2022). Berger et al. (2021) demonstrated that students' perceptions of task value and their expectations for success are key determinants of academic achievement (Aust et al., 2024; Alipour et al., 2023; Kaplar et al., 2022; Cevikbas & Kaiser, 2021). Gamification motivates students by offering challenges, rewards, and opportunities for interaction, which enhance curiosity, self-efficacy, and engagement in learning (Kaya & Ercag, 2023).

Gamification

Gamification in mathematics education involves the application of game elements such as points, challenges, instant feedback, and competition to create a more engaging and participatory learning experience (Zeybek & Saygı, 2023; Jaramillo-Mediavilla et al., 2024). This strategy aims to enhance student engagement and motivation by incorporating mechanisms that trigger enjoyment and a sense of achievement rather than relying solely on conventional instructional methods (Fuentes-Riffo et al., 2023). This approach aligns with Self-Determination Theory (Deci & Ryan, 2020; Guay, 2021), which emphasizes the importance of fulfilling students' basic psychological needs autonomy, competence, and relatedness in order to foster intrinsic motivation. Gamification also reflects the principles of the ARCS model (Attention, Relevance, Confidence, Satisfaction) by enhancing students' attention, the relevance of content, confidence, and satisfaction in the learning process (Kaya & Ercag, 2023; Zhang et al., 2021).

Mathematics is often perceived by students as difficult and abstract, which contributes to low learning motivation especially when taught through traditional, passive instructional methods (Kaplar et al., 2022; Tao et al., 2022). Gamification offers an alternative approach by transforming mathematics learning into a more interactive and exploratory process. Unlike game-based learning, which centers on the use of games as the primary instructional tool, gamification focuses on integrating game elements into learning activities to enhance both motivational and cognitive aspects (Zeng et al., 2024; Bai et al., 2020). Research indicates that students in gamified classrooms demonstrate greater perseverance, improved teamwork, and enhanced problem-solving skills (Ratinho & Martins, 2023; Forsblom et al., 2022). Digital platforms that support gamification also enable more personalized and adaptive learning experiences, which positively influence learning outcomes (Wang et al., 2021; Zhang et al., 2021). By shifting from rote memorization to dynamic conceptual exploration, gamification has proven to be an effective and innovative strategy for significantly improving students' motivation, engagement, and overall mathematics achievement (Alipour et al., 2023; Jaramillo-Mediavilla et al., 2024; Zeng et al., 2024).

Lexical Availability

Lexical availability (LD) measures how students access and understand vocabulary while avoiding repetition. It is regarded as an indicator of writing ability and can be assessed using indices such as MTLD and vocd-D (Shibata, 2021; Rasti-Behbahani & Shahbazi, 2020) in game-based geometry learning. In the context of digital mathematics education, LD serves as a tool to analyze how students internalize concepts through interaction, real-time feedback, and motivational mechanisms embedded within game-based learning applications (Shi, 2022; Vankúš, 2021; Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). Game-based learning environments enable students to learn through scenarios, simulations, and time-based challenges (Shi, 2022). LD plays a vital role in evaluating how students recall and apply geometric vocabulary in interactive tasks. For instance, in an educational geometry game, students may be asked to identify shapes, classify angles, or rapidly apply transformation concepts. The frequency and distribution of geometric terms used in student interactions can be utilized to assess their understanding.

Gamification enhances student engagement by stimulating memory through time-based challenges and reward systems such as points, levels, and badges. Vocabulary retrieval in game-based environments is often more effective than in traditional methods due to factors such as urgency, adaptive repetition, and visual feedback (Rasti-Behbahani & Shahbazi, 2020). Game-based mathematics learning applications frequently provide real-time feedback, allowing students to immediately see whether their answers are correct (Shi, 2022; Vankúš, 2021; Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). LD helps evaluate the effectiveness of such feedback in reinforcing conceptual understanding (Shibata, 2021). For example, in games that require students to identify properties of geometric shapes, immediate feedback accelerates the assimilation of terms such as “right angle,” “line of symmetry,” or “diagonal.” Vocabulary storage and retrieval are influenced by pronunciation, spelling, syntax, and conceptual meaning. In game-based learning, vocabulary reinforcement is facilitated through interactive narratives, audiovisual elements, and adaptive repetition features, which help students connect geometric concepts with their practical applications.

Motivation is a key factor in the success of game-based learning (Yulianto et al., 2024). Through gamification, LD can be used to assess how challenges and incentives within learning applications enhance student engagement and mastery of concepts (Rasti-Behbahani & Shahbazi, 2020; Satsangi et al., 2019). Students who encounter geometry challenges within ranking systems or competitions tend to be more motivated to enrich their vocabulary in order to achieve higher scores (Shi, 2022; Vankúš, 2021). The interest-centered method in LD studies, in which students list terms related to a theme within a limited time, can be adapted into game-based challenges such as interactive quizzes or timed geometric puzzles. In this way, game-based mathematics learning applications not only increase students’ motivation but also broaden their vocabulary in a more meaningful and applicable context.

Methods

Type and Approach of the Study

This study employs a quantitative approach using a quasi-experimental method, specifically adopting a pre-test post-test control group design to evaluate the impact of gamification in geometry learning on students' motivation and academic achievement. This method facilitates a comparison between an experimental group, which receives instruction through gamified learning, and a control group, which is taught using conventional methods. The study was conducted in a secondary school located in the Special Capital Region (DKI) of Jakarta in 2024, involving participants divided into two groups: the experimental group, which learned geometry through a gamification-based platform, and the control group, which received instruction using traditional, non-gamified methods.

The research consisted of four main stages. The first stage was the pre-test (O_1, O_3), during which both groups completed a geometry test and the MotLearn-Q survey to assess their initial levels of motivation and academic performance. The second stage involved the intervention (X), where the experimental group engaged with a gamification platform featuring interactive elements and real-time feedback designed to enhance learning engagement, while the control group continued learning through conventional means. The third stage was the post-test (O_2, O_4), wherein both groups took the same test again to evaluate any changes in motivation and academic performance. The final stage involved data analysis, in which pre-test and post-test results were compared using inferential statistical tests, such as t-tests or ANCOVA, to determine the effectiveness of gamification and explore the relationship between student motivation and academic achievement.

Table 1
Quasi-Experimental One-Group Pre-Test Post-Test Design

Group	Pre-test	Intervensi Gamifikasi	Post-test
Experimental (E)	O_1	X	O_2
Control (C)	O_3	–	O_4

Participants and Sample Selection Criteria

This study involved 10th-grade students who were enrolled in a geometry course at a government-subsidized secondary school in DKI Jakarta. The research population consisted of all 10th-grade students at the school, totaling 89 individuals. To ensure a representative sample and minimize bias, a stratified random sampling technique was employed, stratifying the sample based on gender and academic achievement level. From the population, 45 students were selected for the experimental group, which received the gamified instructional intervention. This group included 25 females (55.6%) and 20 males (44.4%). Meanwhile, the remaining 44 students were assigned to the control group, which received conventional instruction without gamification. The control group comprised 24 females (54.5%) and 20 males (45.5%), maintaining a gender distribution nearly equivalent to that of the experimental group. Stratification ensured that the proportions of gender and academic level in the sample accurately reflected those in the population. Inclusion criteria required students to be enrolled in the geometry course and willing to participate in the study. Exclusion criteria involved students who were not consistently present during the instructional sessions or who faced limitations in accessing the technology required for the intervention. To control for confounding variables, factors such as learning styles, access to technology, and previous experience with gamification were considered. Student participation was entirely voluntary, supported by parental consent and formal approval from the school's academic department.

Table 2
Demographic Characteristics of the Participants

Variable	Category	n	%
Gender	Male	20	44.4%
	Female	25	55.6%
Academic Achievement Level	Low (< 60)	8	17.8%
	Medium (60–79)	21	46.7%
	High (≥ 80)	16	35.5%
Technology Access	Own personal device	37	82.2%
	School-provided device	6	13.3%
	Limited/borrowed device	2	4.5%
Frequency of Technology Use *(in Learning Activities)*	Never (< 1x/week)	3	6.7%
	Rarely (1–2x/week)	10	22.2%
	Often (3 – 4x /week)	20	44.4%
	Very often (≥ 5x/week)	12	26.7%
Prior Experience with Gamification	No experience	18	40.0%
	Has used gamification	27	60.0%
Learning Style	Visual	14	31.1%
	Auditory	9	20.0%
	Kinesthetic	12	26.7%
	Mixed (Visual – Auditory – Kinesthetic)	10	22.2%
Type of Motivation	Intrinsic	26	57.8%
	Extrinsic	19	42.2%

Assumption Testing for Pre-Test and Post-Test

To control for the influence of external factors on the research outcomes, both a pre-test and a post-test were administered. The pre-test results were utilized as covariates in the ANCOVA analysis to ensure that any observed differences in post-test scores were genuinely attributable to the gamification intervention. Before conducting the ANCOVA, two key assumptions were tested: 1) Normality of Data – Assessed using a Q-Q Plot and the Shapiro-Wilk Test. If the data points on the Q-Q Plot align closely with the diagonal line and the *p*-value is greater than 0.05, the data are considered to be normally distributed; and 2) Homogeneity of Variance – Evaluated using a Boxplot and Levene's Test. If the *p*-value exceeds 0.05, the variances across groups are considered homogeneous. The distribution of pre-test scores was analyzed using the Shapiro-Wilk Test to assess data normality, while Levene's Test was applied to verify the equality of variances between the experimental and control groups.

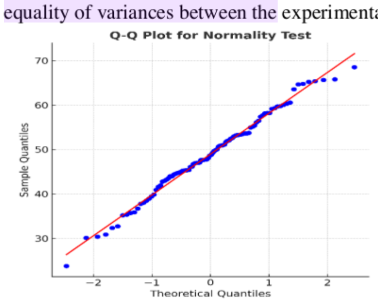

Figure 1. Data Normality

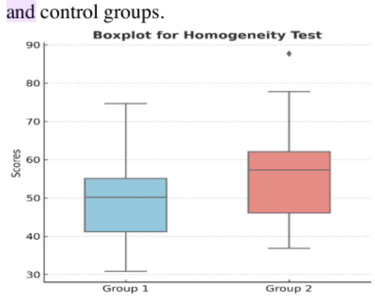

Figure 2. Homogeneity of Variance

The Shapiro–Wilk test indicated that the data in both groups were normally distributed ($p > 0.05$). Furthermore, Levene's Test yielded a p-value of 0.271, suggesting that the variances between the two groups were homogeneous ($p > 0.05$). As presented in Table 3, the Shapiro–Wilk test confirmed that all data sets were normally distributed ($p > 0.05$). Additionally, Levene's Test produced a p-value of 0.271, indicating that the variances between groups were homogeneous ($p > 0.05$).

Table 3

Descriptive Statistics of Students' Pre-Test Scores

Variable	Category	n	Mean	SD	Shapiro–Wilk (p)	Levene's Test (p)
Gender	Male	44	67.8	8.5	0.078 (Normal)	0.293 (Homogeneous)
	Female	45	66.5	9.2	0.091 (Normal)	
Academic Level	High	30	75.4	6.8	0.061 (Normal)	0.256 (Homogeneous)
	Medium	30	68.1	7.9	0.089 (Normal)	
	Low	29	60.7	8.3	0.102 (Normal)	
Learning Style	Visual	28	69.5	7.8	0.073 (Normal)	0.317 (Homogeneous)
	Auditory	30	66.2	8.6	0.081 (Normal)	
	Kinesthetic	31	64.8	9.1	0.094 (Normal)	
Type of Motivation	Intrinsic	42	71.2	7.5	0.068 (Normal)	0.229 (Homogeneous)
	Extrinsic	47	63.9	8.9	0.084 (Normal)	

Instruments and Data Collection

This study employed three primary instruments to measure the variables under investigation. The Learning Process Motivation Evaluation Questionnaire (MotLearn-Q), consisting of 23 items, was used to assess students' intrinsic, extrinsic, and overall motivation. Originally validated in Spain, the instrument demonstrated very high reliability (Cronbach's alpha = 0.93). In the present study, MotLearn-Q was administered to 248 students, yielding similarly high reliability ($\alpha = 0.925$), with subscale reliabilities of intrinsic motivation ($\alpha = 0.912$), extrinsic motivation ($\alpha = 0.918$), and global motivation ($\alpha = 0.925$). These findings confirm the reliability of MotLearn-Q in assessing student motivation in a gamified learning context. The Lexical Availability Test demonstrated strong validity through both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), supported by good model fit indices (CFI = 0.91, TLI = 0.89, RMSEA = 0.06). These analyses confirmed the structure encompassing the categories of geometry, trigonometry, and emotions related to geometry. Content validity was reinforced by Aiken's V index of ≥ 0.85, indicating a high level of expert agreement. Predictive validity was evidenced by a significant correlation with geometry exam scores ($r = 0.62$, $p < 0.001$). The instrument also demonstrated high reliability, with Cronbach's alpha = 0.88, indicating strong internal consistency and temporal stability as shown by a test-retest correlation ($r = 0.81$, $p < 0.001$). Furthermore, item difficulty analysis ($0.30 \leq p \leq 0.70$) confirmed that the instrument effectively discriminated between students with varying levels of lexical availability. The Geometry Test was used to evaluate students' understanding of geometric concepts within a gamified learning environment. The test employed a 7-point grading scale aligned with Chilean evaluation standards. Students were considered to have passed if they obtained a minimum score of 4 ($\geq$60%, equivalent to at least 12 correct responses out of 20 items). The distribution of scores was expected to follow a normal curve, with an average range between 4.5 and 5.2, a standard deviation between 0.8 and 1.1, and a pass rate of approximately 70–80%. This test served as an academic performance indicator of students' mastery of geometric content in a gamified learning setting.

Research Procedure

In this study, a sequence of instructional activities was designed to be implemented over five weeks within the trigonometry unit as part of the geometry curriculum. The instructional approach employed is based on the e-TPACK model, an extension of the Technological Pedagogical Content Knowledge (TPACK) framework. This model emphasizes the integration of Information and Communication Technology (ICT) in classroom instruction. The e-TPACK model incorporates key elements such as digital technologies, Bloom's Digital Taxonomy, and emotional engagement enhanced through gamification. Gamification is applied through a reward system intended to motivate students at each stage of learning. Moreover, this approach aligns learning activities with students' cognitive levels based on Bloom's Digital Taxonomy, thereby enabling learners to engage in progressively complex thinking from basic to higher-order skills. To ensure the model's effectiveness, this study systematically organizes instructional steps, as detailed in Table 4. The table outlines the stages of e-TPACK implementation in the teaching of trigonometry.

Table 4

Instructional Sequence of the e-TPACK Model

Activity	Bloom's Taxonomy	Technology	Emotions Evoked
Independent Research: Students search for information on trigonometric ratios and similarity. They gather materials, highlight key points, and summarize their findings in a notebook.	Remember, Understand, Apply	Google	Interest, Curiosity, Awe
Concept Mapping: Students create a concept map based on their research, then explain and compare their results with peers.	Analyze, Create, Connect, Explain	MindMeister, Cmap Tools	Enthusiasm, Confidence, and Interest
Graph Exploration: Students analyze graphs and angles in a circle, relate angles to trigonometric ratios (sin, cos, tan), and make conjectures about emerging patterns using an interactive simulator.	Analyze, Connect, Predict	PhET Trig Tour	Awe, Approval, Curiosity, Interest
Triangle Side Relations: Students identify relationships among the sides of right-angled triangles and apply trigonometric principles to form appropriate ratios.	Connect, Identify, Predict	Cerebriti Math Games	Confidence, Surprise, Curiosity
Memorization Through Song: Students memorize basic trigonometric values using songs on TikTok and apply them to solve problems.	Remember, Apply	TikTok Educational	Joy, Enthusiasm, Entertainment, Awe
Interactive Quiz: Students complete a Kahoot! quiz to assess their understanding. High scores earn bonus points in assessment.	Recognize, Analyze, Identify	Kahoot!	Curiosity, Joy, and Confidence
Final Evaluation: Students take a test on trigonometric ratios and their applications in various problems.	Remember, Understand, Apply, Analyze, Evaluate	Trigonometry Test	Confidence, Optimism, Approval

The Gamification Approach in Geometry Learning

The gamification approach in geometry learning, as described in this text, involves three main strategies aimed at increasing student engagement: rewards, interactions, and penalties. Within the reward system, students earn emojis as a form of appreciation for their performance in completing learning activities. Interactions occur both among students as players and between students and the teacher acting as the adjudicator. These interactions foster social engagement and collaboration throughout the learning process. Meanwhile, the penalty system is implemented by deducting previously earned emojis when students commit predefined violations. At the end of the module, students can redeem their collected emojis for specific benefits, as outlined in Table 5. This approach differs significantly from traditional methods of teaching geometry, which tend to focus more on understanding trigonometry through calculations involving angles and distances using the Law of Sines and the Law of Cosines. In conventional methods, students are typically assigned exercises that emphasize the mechanical manipulation of mathematical formulas or rote learning, wherein they merely follow calculation steps without fully grasping the practical applications. As a result, for some students, such learning may feel abstract and less relevant to real-life contexts. In this regard, gamification emerges as a more engaging and effective solution by offering a learning experience that is interactive, meaningful, and motivational, encouraging students to develop a deeper understanding of geometric concepts, particularly in relation to fields such as physics, engineering, and astronomy.

Table 5

Benefits of Emojis Collected by Students

Number of Emojis Collected	Benefit
More than 15 emojis	Maximum bonus score (7.0) for the subject.
Between 10 and 14 emojis	Additional 5 points for any evaluation during the semester.
Between 5 and 9 emojis	Removal of the lowest score in process-based tests.
Between 1 and 4 emojis	Additional 2 points for unit assessments.

As shown in Table 5, the more emojis students collect, the greater the academic benefits they receive in the form of bonus points or score improvements in their evaluations.

Statistical Analysis and Research Hypotheses

This study employed a range of statistical methods to measure the impact of gamification on geometry instruction. A *paired t-test* was used to assess improvements in academic achievement (H_1) and students' word production (H_2) by comparing the means of pre-test and post-test scores. The *Wilcoxon Signed-Rank Test* was applied to examine the increase in students' lexical availability index (H_3). Meanwhile, the *Pearson Correlation Test* was utilized to analyze the relationship between global motivation and academic performance (H_5). To ensure the consistency and reliability of the research instruments, *Cronbach's Alpha Reliability Analysis* was conducted. Through this approach, the study evaluates the effectiveness of gamification in enhancing students' understanding of geometry, as well as their motivation and linguistic abilities. Gamification in geometry instruction is expected to yield significant positive effects across various academic and motivational dimensions. Accordingly, this study tests five main hypotheses that reflect the potential benefits of gamification in enriching the learning experience.

H_1 : Gamification enhances academic achievement.
Gamification is considered effective in improving students' understanding and academic performance if the mean post-test score in the experimental group is higher than that of the control group ($\bar{x}\_post\_eksperimental > \bar{x}\_post\_control$).

H_2 : Gamification increases word production in geometry explanations.
Gamification contributes to enriching students' linguistic expression if the number of words in the post-test responses of the experimental group exceeds that of the control group ($\bar{x}\_post\_eksperimental > \bar{x}\_post\_control$).

H_3 : Gamification expands students' vocabulary.
Gamification supports vocabulary development if the increase in the Personal Lexical Availability Index (LAI) in the experimental group is greater than in the control group ($\Delta LAI\_eksperimental > \Delta LAI\_control$).

H_4 : Gamification enhances student motivation.
Gamification improves student engagement in learning if the post-test motivation score in the experimental group is higher than in the control group ($motivation\_post\_eksperimental > motivation\_post\_control$).

H_5 : There is a relationship between motivation and academic achievement in gamified learning.
Gamification is instrumental in fostering both engagement and academic success if the correlation between global motivation and academic achievement in the experimental group is stronger than in the control group ($r\_eksperimental > r\_control$).

Results and Discussion

To test the first hypothesis (H_1), which posits that gamification enhances academic achievement, a comparative analysis of pre-test and post-test scores was conducted for both the experimental and control groups. A paired-samples t-test was employed to determine whether a significant difference existed in academic performance before and after the gamification intervention. Prior to the analysis, the Shapiro–Wilk normality test was applied to ensure that the data were normally distributed. The results indicated that the p-value for the pre-test was 0.062 and for the post-test was 0.189, confirming that the assumption of normality was satisfied. Subsequently, the results of the Student's t-test revealed a p-value of 0.000, leading to the rejection of the null hypothesis (H_0). This finding demonstrates a significant improvement in academic performance following the implementation of gamification in geometry instruction (see Table 6).

Table 6
Results of Paired-Samples t-Test for Academic Achievement

Group	Comparison	M	SD	MSE	CI	t	df	Sig.	Cohen's d
Experiment Class	Pre-test vs. Post-test	-11.572	6.630	0.988	[-13.636, -9.652]	-11.781	44	0.000	1.141
Control Class	Pre-test vs. Post-test	-10.851	6.400	0.956	[-12.950, -8.750]	-11.230	43	0.000	1.082

Table 6 presents the results of the paired-samples t-test for academic achievement. Both the experimental group (M = -11.572, d = 1.141) and the control group (M = -10.851, d = 1.082) showed significant improvements ($p < 0.05$) from pre-test to post-test. However, the experimental group demonstrated a slightly greater increase, as evidenced by a higher mean difference and a larger effect size. These results suggest that the gamification intervention had a more substantial impact on academic achievement compared to conventional instructional methods. Therefore, the findings support the hypothesis that gamification enhances academic achievement by creating a more engaging and effective learning environment.

Lexical Analysis

The second hypothesis (H_2) posits that gamification enhances word production in geometry explanations, which can be substantiated if the number of words in the post-test of the experimental group exceeds that of the control group. Initially, the number of words generated by students during both phases of the study was analyzed. To compare the average number of words produced by students across the three primary domains of interest, emotions, geometry, and trigonometry, a series of comparative analyses was conducted. Subsequently, statistical analyses were applied to calculate the Lexical Availability Index (LAI) and the Proportional Lexical Availability Index (LAIp) using the Dispogen software (version 2014). In this study, students were given a lexical availability test to identify words associated with the emotional domain. The prompt provided was: *"What emotions do you associate with geometry?"* Additionally, for the geometry and trigonometry domains, students were asked to generate a list of terms related to each concept (see Table 7). Statistical analyses were carried out while considering the normality of data distribution. The Student's t-test was applied for normally distributed data, while the Wilcoxon test was used for non-normally distributed data.

Table 7

Lexical Availability Test Results and Statistical Analysis

Area of Interest	$\bar{x} \pm SD$ (Experiment)	$\bar{x} \pm SD$ (Control)	W	p-value (Normality)	Statistical Test	p-value
Emotion & Geometry	12.4 ± 3.1	12.2 ± 3.0	0.967	0.067 (normal)	t-test	0.215
Geometry	15.8 ± 4.2	15.5 ± 3.6	0.972	0.082 (normal)	t-test	0.089
Trigonometry	9.6 ± 2.8	5.81 ± 2.5	0.891	0.013 (not normal)	Wilcoxon test	0.000

Table 7 shows that the increase in lexical availability was significant only in the trigonometry domain ($p = 0.000$), where the experimental group (9.6 ± 2.8) outperformed the control group (5.81 ± 2.5). Meanwhile, for Emotion & Geometry and Geometry, the differences between the experimental and control groups were not statistically significant ($p > 0.05$). This suggests that the applied instructional method primarily impacted the understanding of trigonometric concepts, with a lesser effect on emotional associations and geometrical understanding. Furthermore, as shown in Table 8, the statistical analysis indicates a significant increase in trigonometric lexical availability in the experimental group compared to the control. The average number of words in the experimental group rose from 255 ($M = 5.79$) to 492 ($M = 10.93$) ($p = 0.000$), whereas the control group showed only a slight increase from 250 ($M = 5.75$) to 258 ($M = 5.81$) ($p > 0.05$). Conversely, in the domains of emotion and geometry, neither the experimental nor the control group exhibited significant changes ($p > 0.05$). These findings confirm the effectiveness of context-based instructional strategies in enhancing lexical richness in trigonometry, while their influence on the domains of emotion and geometry remains limited.

Table 8
Words Produced in Each Centre of Interest

Category	Group	Pre-test (N, M, SD)	Post-test (N, M, SD)	ΔM	p-value
Emotion	Experimental	244 (5.42, 1.21)	211 (4.68, 1.15)	-0.74	0.084
	Control	240 (5.40, 1.18)	238 (5.38, 1.17)	-0.02	0.915
Geometry	Experimental	557 (12.37, 2.54)	524 (11.64, 2.48)	-0.73	0.076
	Control	550 (12.40, 2.50)	545 (12.35, 2.49)	-0.05	0.967
Trigonometry	Experimental	255 (5.79, 1.32)	492 (10.93, 1.75)	+5.14	0.000
	Control	250 (5.75, 1.30)	258 (5.81, 1.33)	+0.06	0.834

The analysis of Table 8 reveals a statistically significant increase in trigonometric lexical items within the experimental group ($\Delta M = +5.14$, $p = 0.000$), while the control group did not exhibit a meaningful change ($\Delta M = +0.06$, $p = 0.834$). In contrast, the emotion and geometry categories did not show significant differences ($p > 0.05$), indicating that the intervention specifically impacted trigonometry. This improvement partially supports the second hypothesis, as evidenced by the higher average number of words in the post-test. The absence of significant changes in the emotion and geometry categories may be attributed to the possible substitution of words during the post-test or could be influenced by participants' varying levels of motivation throughout the study.

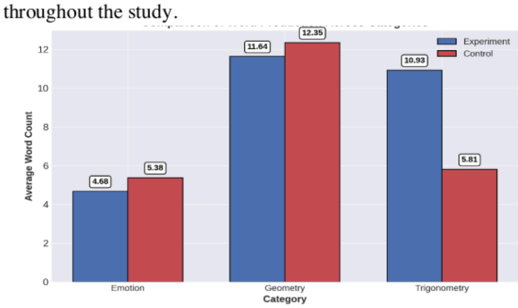

Figure 3. Compararison of Word Production Across Categories

Lexical Availability Index in Emotions, Geometry, and Trigonometry

The Lexical Availability Index (LAI) was employed to analyze lexical changes across three main categories: emotions related to geometry, geometric terminology, and trigonometric terminology. The results indicate that the intervention had varying impacts across these categories.

1. Emotions Related to Geometry.

   In the experimental group, there was a significant shift from negative to positive lexical items following the intervention. Prior to the intervention, the most dominant words were *fear* (32.7%), *sadness* (30.2%), and *laziness* (26.2%). After the intervention, these words showed a marked decrease, accompanied by a notable increase in positive lexical items such as *happiness* (41.1%), *joy* (30.6%), and *thrill* (21.4%). In contrast, the control group exhibited no statistically significant change ($p > 0.05$). Negative words remained predominant, including *fear* (31.5%), *sadness* (28.9%), and *laziness* (25.1%), while the increase in positive terms such as *happiness* (39.5%), *joy* (29.8%), and *thrill* (20.5%) did not represent a meaningful difference.

2. Geometric Terminology.
   In the category of geometric terminology, neither the experimental nor the control group demonstrated significant changes ($p > 0.05$). In the experimental group, there was a slight increase in the frequency of geometric terms. In the pre-test, the most frequently mentioned words were *square* (45.6%), *triangle* (41.3%), and *area* (39.6%). After the intervention, minor shifts were observed, with *angle* (46.8%), *triangle* (45.8%), and *square* (41.5%) becoming more prominent. In the control group, changes were minimal. The dominant terms remained *square* (44.5%), *triangle* (40.2%), and *area* (38.5%) in the pre-test, and *angle* (45.5%), *triangle* (44.7%), and *square* (40.5%) in the post-test. These results suggest that the intervention had no substantial effect on students' geometric terminology.
3. Trigonometric Terminology.
   In the category of trigonometric terminology, the experimental group demonstrated a significant increase in the number of terms ($p = 0.000$). The most dominant words in the pre-test were *triangle* (60.5%), *geometry* (26.4%), and *number* (24.9%). After the intervention, there was a noticeable shift, with a significant increase in the terms *triangle* (49.5%), *cosine* (48.2%), and *sine* (46.7%). In contrast, the control group did not show any significant change ($p > 0.05$), with the dominant pre-test terms remaining *triangle* (59.0%), *geometry* (25.5%), and *number* (24.0%). The post-test revealed only minimal changes, with *triangle* (48.2%), *cosine* (47.0%), and *sine* (45.5%) being the most common.

To test hypothesis H_3, a statistical analysis was conducted by comparing the mean differences in the Lexical Availability Index (LAI) before and after the intervention between the experimental and control groups. An independent t-test analysis revealed that gamification significantly improved the LAI in the trigonometric category ($t(87) = 3.28$, $p = 0.0015$), with a greater increase observed in the experimental group (ΔMean = 0.109) compared to the control group (ΔMean = 0.044, Cohen's d = 0.695). Conversely, in the geometry category, no significant difference was found ($t(87) = 0.59$, $p = 0.555$), suggesting that gamification had a stronger impact on expanding trigonometric vocabulary than geometric terminology.

Table 9

Independent T-Test Analysis for Trigonometry and Geometry Categories

Category	Group	ΔMean (Post - Pre)	SD Post	n	t-value	p-value	Cohen's d
Trigonometry	Experimental	0.109	0.095	45	3.28	0.0015	0.695
	Control	0.044	0.092	44			
Geometry	Experimental	0.023	0.098	45	0.59	0.555	0.126
	Control	0.011	0.093	44			

As shown in Table 9, gamification significantly increased the Lexical Availability Index (LAI) for the trigonometry category ($t(87) = 3.28$, $p = 0.0015$), with a greater improvement in the experimental group (ΔMean = 0.109) than in the control group (ΔMean = 0.044, d = 0.695). In contrast, no significant difference was found in the geometry category ($t(87) = 0.59$, $p = 0.555$), underscoring the stronger effectiveness of gamification in enhancing trigonometric vocabulary.

Table 10 below presents the top three most available words in each of the three main categories: emotion, geometric terminology, and trigonometric terminology, based on the pre-test and post-test results.

Table 10

Top Three Most Available Words by Category of Interest

Category	Group	Pre-Test (LAI)			Post-Test (LAI)		
		Word 1	Word 2	Word 3	Word 1	Word 2	Word 3
Emotion	Experimen	Fear (0.327)	Sadness (0.302)	Laziness (0.262)	Happiness (0.411)	Joy (0.306)	Thrill (0.214)
	Control	Fear (0.315)	Sadness (0.289)	Laziness (0.251)	Happiness (0.395)	Joy (0.298)	Thrill (0.205)
Geometry	Experimen	Square (0.456)	Triangle (0.413)	Area (0.396)	Angle (0.468)	Triangle (0.458)	Square (0.415)
	Control	Square (0.445)	Triangle (0.402)	Area (0.385)	Angle (0.455)	Triangle (0.447)	Square (0.405)
Trigonometry	Experimen	Triangle (0.605)	Geometry (0.264)	Number (0.249)	Triangle (0.495)	Cosine (0.482)	Sine (0.467)
	Control	Triangle (0.590)	Geometry (0.255)	Number (0.240)	Triangle (0.482)	Cosine (0.470)	Sine (0.455)

The findings of the study indicate significant changes in emotional expression, understanding of geometry, and comprehension of trigonometric concepts between the pre-test and post-test phases. In terms of emotional aspects, students in the experimental group initially displayed a predominance of negative emotions, such as fear (0.327), sadness (0.302), and laziness (0.262). However, following the intervention, there was a notable shift toward positive emotions, with happiness (0.411), joy (0.306), and thrill (0.214) emerging as the most dominant. A similar trend was observed in the control group, although the increase in positive emotions was less pronounced happiness (0.395), joy (0.298), and thrill (0.205). In the domain of geometry, the use of terminology in the experimental class shifted from basic to more complex concepts. During the pre-test, the most frequently mentioned terms were *square* (0.456), *triangle* (0.413), and *area* (0.396). After the intervention, the focus shifted to more abstract concepts, with *angle* (0.468) becoming the most dominant term, followed by *triangle* (0.458) and *square* (0.415). Although the control group exhibited a similar pattern, the magnitude of change was smaller (*angle* 0.455, *triangle* 0.447, *square* 0.405).

Regarding trigonometric concepts, the experimental group demonstrated a significant increase in the variety of terms used. In the pre-test, the majority of students mentioned only *triangle* (0.605), *geometry* (0.264), and *number* (0.249). After the intervention, there was a marked rise in the use of specific terminology, such as *cosine* (0.482) and *sine* (0.467), with *triangle* still dominant (0.495). Meanwhile, the control group also showed improvement but with lower values (*cosine* 0.470, *sine* 0.455, *triangle* 0.482), indicating a more substantial impact of the intervention on the experimental class. Overall, the intervention proved effective in enhancing student motivation, conceptual understanding, and the use of academic language in learning geometry and trigonometry. The impact was notably more significant in the experimental group than in the control group. Statistical analysis revealed that both intrinsic and extrinsic motivation scores from the MotLearn-Q questionnaire increased significantly from pre-test to post-test ($p < 0.05$), particularly within the experimental group (Table 9).

Accordingly, hypothesis H_3, which posits that gamification contributes to vocabulary expansion, especially in trigonometric terminology, was supported, with greater improvement observed in the experimental group compared to the control group. Thus, the null hypothesis (H_0) was rejected for the trigonometry category, confirming the effectiveness of gamification in expanding vocabulary in this area. Conversely, no significant difference was found in the geometry category, leading to the acceptance of H_0 for that domain.

Table 11

Statistical Analysis of Student Improvement

Variable	Category	Experimental (N = 45)	Z / χ^2 / F / t	p-value	Control (N = 44)	Z / χ^2 / F / t
Gender	Male (Δ +4.5%, p = 0.006)	12 students improved (54.5%)	Z = -2.98	0.003	10 students improved (50.0%)	Z = -2.75
	Female (Δ +8.7%, p = 0.005)	11 students improved (47.8%)	Z = -3.12	0.002	9 students improved (39.1%)	Z = -2.80
Academic Level (p =	High (Δ +20.0%, p = 0.008)	9 students improved (60.0%)	χ^2 = 7.82	0.005	6 students improved (40.0%)	χ^2 = 6.75
	Medium (Δ +6.7%, p = 0.015)	7 students improved (46.7%)	χ^2 = 6.42	0.011	6 students improved (40.0%)	χ^2 = 5.98
	Low (Δ +6.6%, p = 0.023)	5 students improved (33.3%)	χ^2 = 5.87	0.017	4 students improved (26.7%)	χ^2 = 5.20
Learning Style	Visual (Δ +14.2%, p = 0.012)	8 students improved (57.1%)	F(2,86) = 4.92	0.008	6 students improved (42.9%)	F(2,85) = 4.10
	Auditory (Δ +6.7%, P = 0.014)	7 students improved (46.7%)	F(2,86) = 4.67	0.009	6 students improved (40.0%)	F(2,85) = 4.05
	Kinesthetic (Δ +6.2%, P = 0.018)	6 students improved (37.5%)	F(2,86) = 4.23	0.013	5 students improved (31.3%)	F(2,85) = 3.89
Motivation Type	Intrinsic (Δ +14.3%, P = 0.004)	15 students improved (71.4%)	t(87) = -3.28	0.001	12 students improved (57.1%)	t(85) = -2.95
	Extrinsic (Δ +12.5%, p = 0.008)	13 students improved (54.2%)	t(87) = -2.97	0.003	10 students improved (41.7%)	t(85) = -2.65

The findings confirm that both intrinsic and extrinsic motivation scores significantly increased within the experimental group ($p < 0.05$), whereas the control group experienced a more modest improvement. The increase was particularly notable among students with intrinsic motivation (71.4% in the experimental group vs. 57.1% in the control group) and those with high academic achievement (60.0% vs. 40.0%). In terms of learning styles, visually oriented students showed the highest improvement (57.1% experimental vs. 42.9% control), suggesting that gamification is more effective for learners who rely on visual processing. Additionally, male students in the experimental group experienced a greater increase in motivation (54.5%) compared to female students (47.8%). Thus, as post-test motivation scores were significantly higher in the experimental class than in the control class,

hypothesis H_4 was accepted, confirming that gamification significantly enhances students' motivation in learning contexts.

The Relationship Between Academic Achievement and Global Motivation

Students' academic achievement was measured using two written tests: one administered prior to the geometry unit and the other following the completion of the unit, which incorporated a gamified learning approach. Both tests were scored on a scale from 1 to 7, in accordance with the school's grading criteria, which require a minimum proficiency level of 60% to achieve a passing grade of 4. To measure student motivation, the MotLearn-Q instrument was employed. Scores for various motivation categories were calculated by summing the values assigned to each response within the corresponding category. The analysis of results accounted for differences based on gender and age. Raw scores for global, intrinsic, and extrinsic motivation were subsequently converted into percentile scores to facilitate interpretation. These scores ranged from 0 to 100, with a value of 50 representing the average level of student motivation. Scores below 50 indicated low motivation, while scores above 50 signified high motivation. The conversion of raw scores to percentiles was conducted based on a scale aligned with students' academic level, learning style, gender, and type of motivation (intrinsic or extrinsic). To examine the relationship between the two variables in a small sample ($n \leq 50$), the Shapiro–Wilk normality test was applied. The results indicated that the academic achievement variable was normally distributed, with a significance level of 0.062 ($p > 0.05$). In contrast, the motivation variable was not normally distributed, with a significance level of 0.005 ($p < 0.05$). Descriptive statistics confirmed this distributional difference between the two quantitative variables. Given that one of the variables was not normally distributed, the correlation was analyzed using Spearman's non-parametric test. Table 7 presents the results of the correlation analysis between academic achievement and motivation in both the experimental and control groups during the pre-test and post-test stages.

Table 7

Correlation Between Academic Achievement and Motivation in Pre-Test and Post-Test (Experimental vs. Control Groups)

Group	Test	Variables	Spearman's ρ	Significance (p-value)
Experimental	Pre-Test	Academic Achievement → Motivation	0.472	0.038
	Pre-Test	Motivation → Academic Achievement	0.472	0.038
	Post-Test	Academic Achievement → Motivation	0.589	0.012
	Post-Test	Motivation → Academic Achievement	0.589	0.012
Control	Pre-Test	Academic Achievement → Motivation	0.298	0.102
	Pre-Test	Motivation → Academic Achievement	0.298	0.102
	Post-Test	Academic Achievement → Motivation	0.365	0.085
	Post-Test	Motivation → Academic Achievement	0.365	0.085

Spearman's correlation analysis revealed that in the experimental group, the relationship between motivation and academic achievement increased significantly from the pre-test ($\rho = 0.472$, $p = 0.038$) to the post-test ($\rho = 0.589$, $p = 0.012$). In contrast, the control group also showed an increase in correlation from $\rho = 0.298$ to $\rho = 0.365$; however, the correlation remained weak and statistically insignificant ($p > 0.05$). Consequently, Hypothesis H_5 was accepted, indicating that gamification not only enhances motivation and academic achievement individually but also strengthens the relationship between the two, making students more motivated to achieve better learning outcomes.

Discussion

Recent research indicates that the success of learning is not solely determined by cognitive abilities but is also significantly influenced by students' motivation to engage actively in the learning process (Forsblom et al., 2022; Tao et al., 2022). In this context, gamification the integration of game elements into educational activities has gained increasing attention for its ability to make learning more engaging and interactive (Jaramillo-Mediavilla et al., 2024; Ratinho & Martins, 2023). Gamification has been shown to enhance intrinsic motivation, which in turn fosters the development of critical thinking skills such as decision-making, problem-solving, and independent learning (Kaya & Ercag, 2023). Jaramillo-Mediavilla et al. (2024) emphasize that gamification design must align with curriculum objectives in order to actively encourage exploration of material and completion of challenging tasks. Their study further demonstrates that well-designed gamification strategies not only emotionally engage students but also significantly improve academic performance, including in mathematics. Forsblom et al. (2022) identified a connection between cognitive appraisal, achievement emotions, and mathematics learning outcomes, underlining the vital role of motivation in supporting academic success. Similarly, Wang et al. (2021) noted that students' engagement in learning mathematics is significantly influenced by metacognition, interest, and self-regulation. These findings reinforce the argument that student motivation can be enhanced through innovative approaches such as gamification, which fosters more enjoyable and meaningful learning experiences. Rasti-Behbahani and Shahbazi (2020) found that digital game-based tasks significantly improve vocabulary comprehension and mastery, suggesting the effectiveness of this approach across various learning contexts, including mathematics. Likewise, Papp (as cited in Vankúš, 2021) observed that students at various educational levels view gamification as an appealing strategy that does not require expensive technology to implement effectively.

In the context of mathematics, especially geometry, students often perceive the subject as difficult and overly reliant on memorization (Satsangi et al., 2019). However, Satsangi et al. also highlight that video modeling and gamification-based approaches help students with learning difficulties better understand contextual geometry problems. Geometry plays a crucial role in developing logical reasoning and spatial thinking; thus, its instruction should be designed to be interactive and application-oriented (Kaplar et al., 2022). As a practical application of this approach, the present study implemented an incentive- and reward-based gamification strategy to enhance student engagement. Results indicated a marked improvement in learning motivation following the gamified intervention. During the initial stage (pre-test), students frequently expressed negative emotions such as "fear," "laziness," and "boredom" toward mathematics. However, post-intervention, there was a notable shift toward positive emotions, including "happiness," "excitement," and "curiosity." These findings support those of Kaya and Ercag (2023), who concluded that gamification enhances emotional and motivational aspects of learning while also reshaping students' perceptions of subjects initially deemed difficult.

Gamification is an innovative educational approach that incorporates game elements into the learning environment to increase student engagement, strengthen teacher-student interaction, and enrich the overall learning experience. This approach contributes not only to increased motivation but also positively impacts students' academic performance (Ratinho & Martins, 2023; Zhang et al., 2021). It is important to distinguish between gamification and game-based learning. Gamification refers to the integration of game elements such as points, levels, or challenges into non-game contexts to promote desired behaviors. In contrast, game-based learning involves the use of games explicitly as part of the instructional process (Jaramillo-Mediavilla et al., 2024; Vankúš, 2021). In the field of mathematics education, gamification has proven to positively influence both motivation and academic achievement. Through experimental research, Kaya and Ercag (2023) demonstrated that challenge-based gamification programs significantly improve learning outcomes, intrinsic motivation, and students' experience of flow. These findings align with those of Rasti-Behbahani and Shahbazi (2020), who reported that digital game-based tasks effectively enhance knowledge acquisition and student engagement.

Zhang et al. (2021) also support this perspective, revealing that gamification platforms such as Classcraft significantly boost academic achievement and learning motivation. Moreover, a systematic review by Ratinho and Martins (2023) found that gamification strategies greatly contribute to student motivation at both secondary and higher education levels. Additionally, Jaramillo-Mediavilla et al. (2024) assert that the incorporation of game elements into instruction not only drives student engagement but also has a direct effect on academic performance. Even with relatively minimal resource investment, gamified dashboards can yield significant outcomes in large-scale STEM education. Therefore, to design effective and meaningful mathematics instruction, educators are encouraged to adopt adaptive, technology-driven teaching strategies. Integrating gamification into the learning process not only enhances the appeal of mathematics instruction but also strengthens students' intrinsic motivation (Guay, 2021; Morris et al., 2022), ultimately leading to improved academic performance.

Conclusion

This study aimed to develop a gamification-based didactic module for teaching geometry in secondary schools to enhance student motivation. In addition, it investigated the correlation between motivation and academic achievement within a selected cohort, alongside other contributing variables. The geometry unit focused specifically on fundamental concepts of trigonometric ratios. To support the learning process, gamified activities were implemented, incorporating game mechanics, a reward-and-penalty system, and interactive elements. Each component was represented through emojis that students collected throughout the module, serving to maintain their motivation and engagement. Digital platforms such as PhET, Kahoot, and TikTok were also utilized to increase student participation in interactive learning.

The intervention results revealed improvements in students' motivation, engagement, responsibility, and self-confidence in understanding the material. Motivation levels were measured using the Motivation Evaluation Questionnaire in the Learning Process (MotLearn-Q), which indicated a significant increase in overall motivation. The post-test results supported the fourth research hypothesis, showing higher global motivation scores compared to the pre-test. A parametric t-test further confirmed a significant increase in academic performance, with average pre-test scores rising from 40.9 to 52.6 in the post-test. This difference highlights the effectiveness of gamification in enhancing learning outcomes.

Furthermore, the study analyzed the Lexical Availability Index (LAI) to explore the relationship between emotional vocabulary, motivation, and student engagement. This analysis assessed word dominance within the cognitive structure and the alignment between individual and group lexicons. The Spearman test confirmed a significant correlation between motivation and academic achievement, reinforcing the hypothesis that increased global motivation positively impacts academic performance. Overall, the findings affirm that gamification is an effective pedagogical strategy for improving mathematics learning in secondary education. Gamification functions as a motivational trigger, reducing stress from challenging academic tasks while alleviating boredom and other learning barriers. The integration of digital tools enabled students to develop more effective learning strategies, improve conceptual understanding, and achieve higher academic success.

Limitations and Directions for Future Research

Despite demonstrating that gamification positively influences motivation and academic achievement, several limitations should be acknowledged. First, although the observed effects were consistent among Grade 10 students, studies with larger sample sizes may yield more generalizable results. Additionally, since the sample was drawn from a single educational institution, the findings may not be fully applicable to broader populations. Future studies should involve students from diverse backgrounds and institutions, as cultural factors may influence the effectiveness of gamification. The inclusion of a control group would also help provide a clearer understanding of gamification's actual impact.

Moreover, the duration of the intervention in this study may have been too short to observe the long-term effects of gamification on motivation and academic achievement. Future research is encouraged to implement interventions over longer periods to yield more comprehensive results. Lastly, although this study focused on gamification as the primary factor influencing motivation and academic performance, other elements such as student characteristics, teacher effectiveness, and family support, also play a role. Future studies integrating these factors will provide a more holistic understanding of the multiple dimensions affecting student motivation and academic success.

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