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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.

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?

Methods

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.

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.

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

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	Remember, Understand, Apply	*Google*	Interest, Curiosity, Awe	

Activity	Bloom's Taxonomy	Technology	Emotions Evoked
gather materials, highlight 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

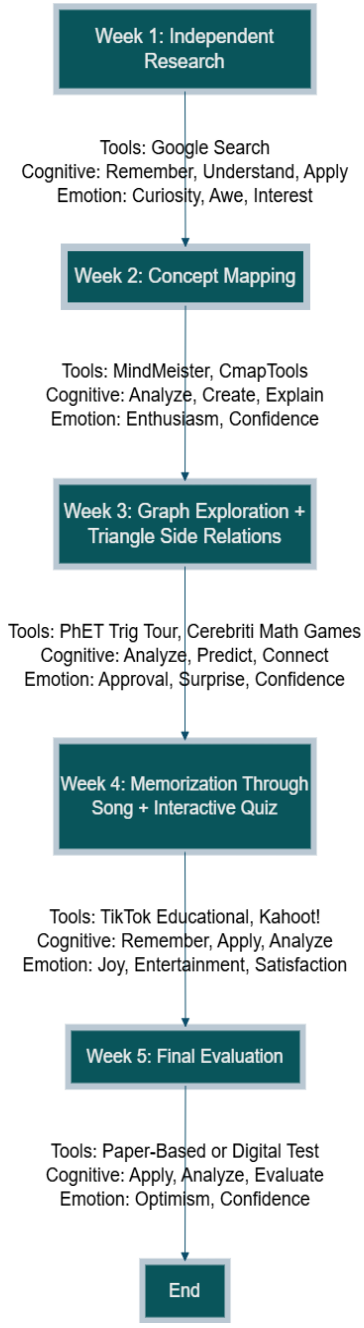

Figure 1. Instructional Flow of e-TPACK-Based Trigonometry Module

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

Impact of Gamification on Geometry Achievement

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

Gamification and 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

Gamification and 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 ($\Delta Mean = 0.109$) compared to the control group ($\Delta Mean = 0.044$, 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 / 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%)	$\chi^2 = 7.82$	0.005	6 students improved (40.0%)	$\chi^2 = 6.75$
	Medium (Δ +6.7%, p = 0.015)	7 students improved (46.7%)	$\chi^2 = 6.42$	0.011	6 students improved (40.0%)	$\chi^2 = 5.98$
	Low (Δ +6.6%, p = 0.023)	5 students improved (33.3%)	$\chi^2 = 5.87$	0.017	4 students improved (26.7%)	$\chi^2 = 5.20$
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

Gamification and 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.

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-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.

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References

Akman, E., & Çakır, R. (2020). The effect of educational virtual reality games on primary school students' achievement and engagement in mathematics. *Interactive Learning Environments.* Advance online publication. https://doi.org/10.1080/10494820.2020.1841800

Bai, S., Hew, K.F., & Huang, B. (2020). Does Gamification Improve Student Learning Outcomes? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educational Research Review*, *33.* https://doi.org/10.1016/j.edurev.2020.100322

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, *25*(24), 3186–3191. https://doi.org/10.1097/00007632-200012150-00014

Bouchée, T., de Putter-Smits, L., Thurlings, M., & Pepin, B. (2021). Towards a better understanding of conceptual difficulties in introductory quantum physics courses. *Studies in Science Education*, *58*(2), 183–202. https://doi.org/10.1080/03057267.2021.1963579

Dahri, N.A., Yahaya, N., Al-Rahmi, W.M., Noman, H.A., Alblehai, F., Kamin, Y.B., Soomro, R.B., Shutaleva, A., & Al-Adwan, A. S. (2024). Investigating the motivating factors that influence the adoption of blended learning for teachers' professional development. *Heliyon, 10*(15): e34900. https://doi.org/10.1016/j.heliyon.2024.e34900

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics: And Sex and Drugs and Rock 'N' Roll* (4th Edition). Sage, Los Angeles, London, New Delhi.

Forsblom, L., Pekrun, R., Loderer, K., & Peixoto, F. (2022). Cognitive appraisals, achievement emotions, and students' math achievement: A longitudinal analysis. *Journal of Educational Psychology, 114*(2), 346–367. https://doi.org/10.1037/edu0000671

Fuentes-Riffo, K., Salcedo-Lagos, P., Sanhueza-Campos, C., Pinacho-Davidson, P., Friz-Carrillo, M., Kotz-Grabole, G., & Espejo-Burkart, F. (2023). The Influence of Gamification on High School Students' Motivation in Geometry Lessons. *Sustainability*, *15*(21), 15615. https://doi.org/10.3390/su152115615

Guay, F. (2021). Applying Self-Determination Theory to Education: Regulations Types, Psychological Needs, and Autonomy-Supporting Behaviors. *Canadian Journal of School Psychology, 37*(1), 75-92. https://doi.org/10.1177/08295735211055355

Herrera, L.M., Ordóñez, S. J., & Ruiz-Loza, S. (2024). Enhancing mathematical education with spatial visualization tools. *Front. Educ*. *9*: 1229126. https://doi.org/10.3389/feduc.2024.1229126

Isnawan, M. G., Alsulami, N. M., & Sudirman, S. (2024). Optimizing prospective teachers' representational abilities through didactical design-based lesson study. *International Journal of Evaluation and Research in Education (IJERE)*, *13*(6), 4004–4016. https://doi.org/10.11591/ijere.v13i6.29826

Jafaruddin, J., & Chen, W.-H. (2023). Fostering ethnomathematics in projective geometry: A hypnoteaching framework for effective distance learning. *Southeast Asian Mathematics Education Journal*, *13*(2), 85–108. https://doi.org/10.46517/seamej.v13i2.240

Jaramillo-Mediavilla, L., Basantes-Andrade, A., Cabezas-González, M., & Casillas-Martín, S. (2024). Impact of Gamification on Motivation and Academic Performance: A Systematic Review. *Education Sciences*, *14*(6), 639. https://doi.org/10.3390/educsci14060639

Kaplar, M., Radović, S., Veljković, K. *et al.* (2022). The Influence of Interactive Learning Materials on Solving Tasks That Require Different Types of Mathematical

Reasoning. *Int J of Sci and Math Educ* ***20***, 411–433. https://doi.org/10.1007/s10763-021-10151-8

Kaya, O.S., & Ercag, E. (2023). The impact of applying challenge-based gamification program on students' learning outcomes: Academic achievement, motivation and flow. *Educ Inf Technol* **28**, 10053–10078. https://doi.org/10.1007/s10639-023-11585-z

Kin, L. C. (2015). Educating the educators: Technology-enhanced mathematics teaching and learning. *Southeast Asian Mathematics Education Journal*, *5*(1), 63–72. https://doi.org/10.46517/seamej.v5i1.33

Kuncoro, K. S., Zakkia, A., Sulistyowati, F., & Kusumaningrum, B. (2021). Students' mathematical critical thinking based on self-esteem through problem-based learning in geometry. *Southeast Asian Mathematics Education Journal*, *11*(1), 41–52. https://doi.org/10.46517/seamej.v11i1.122

Makransky, G., & Petersen, G. B. (2021). The Cognitive Affective Model of Immersive Learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review,* *33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2

Mamekova, A. T., Toxanbayeva, N. K., Naubaeva, K. T., Ongarbayeva, S. S., & Akhmediyeva, K. N. (2021). A Meta-Analysis on the Impact of Gamification over Students' Motivation. *Journal of Intellectual Disability - Diagnosis and Treatment*, *9*(4), 417–422. https://doi.org/10.6000/2292-2598.2021.09.04.9

Mamolo, L. A. (2022). Online Learning and Students' Mathematics Motivation, Self-Efficacy, and Anxiety in the New Normal. *Education Research International*, 9439634, 1-10. https://doi.org/10.1155/2022/9439634

Morris, L. S., Grehl, M. M., Rutter, S. B., Mehta, M., & Westwater, M. L. (2022). On what motivates us: a detailed review of intrinsic v. extrinsic motivation. *Psychological Medicine*, *52*(10), 1801–1816. https://doi.org/10.1017/S0033291722001611

OECD. (2023). *OECD Economic Outlook, Volume 2023* Issue 1, No. 113, OECD Publishing, Paris. https://doi.org/10.1787/ce188438-en

Priyadi, O., Ramadhan, I., Sensuse, D.I., Suryono, R.R., Kautsarina (2023). *Gamification in Software Development: Systematic Literature Review. In: Ben Ahmed, M., Abdelhakim, B.A., Ane, B.K., Rosiyadi, D. (Eds.), Emerging Trends in Intelligent Systems and Network Security*. Lecture Notes on Data Engineering and Communications Technologies, 147. Springer, Cham. https://doi.org/10.1007/978-3-031-15191-0_37

Rasti-Behbahani, A., & Shahbazi, M. (2020). Investigating the effectiveness of a digital game-based task on the acquisition of word knowledge. *Computer Assisted Language Learning*, *35*(8), 1920–1945. https://doi.org/10.1080/09588221.2020.1846567

Ratinho, E., & Martins, C. (2023). The role of gamified learning strategies in student's motivation in high school and higher education: A systematic review. *Heliyon, 9*(8): e19033. https://doi.org/10.1016/j.heliyon.2023.e19033

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology, 61,* Article 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

Salcedo-Lagos, P., Morales-Candia, S., Fuentes-Riffo, K., Rivera-Robles, S., & Sanhueza-Campos, C. (2021). Teachers' Perceptions Analysis on Students' Emotions in Virtual Classes during COVID-19 Pandemic: A Lexical Availability Approach. *Sustainability*, *13*(11), 6413. https://doi.org/10.3390/su13116413

Satsangi, R., Hammer, R., & Bouck, E. C. (2019). Using Video Modeling to Teach Geometry Word Problems: A Strategy for Students with Learning Disabilities. *Remedial and Special Education, 41*(5), 309-320. https://doi.org/10.1177/0741932518824974

Schoevers, E.M., Leseman, P.P.M. & Kroesbergen, E.H. (2020). Enriching Mathematics Education with Visual Arts: Effects on Elementary School Students' Ability in Geometry and Visual Arts. *Int J of Sci and Math Educ* ***18****,* 1613–1634. https://doi.org/10.1007/s10763-019-10018-z

Schutera, S., Schnierle, M., Wu, M., Pertzel, T., Seybold, J., Bauer, P., Teutscher, D., Raedle, M., Heß-Mohr, N., Röck, S., & Krause, M. J. (2021). On the Potential of Augmented Reality for Mathematics Teaching with the Application cleARmaths. *Education Sciences*, *11*(8), 368. https://doi.org/10.3390/educsci11080368

Shi, J. (2022). Innovating the Instruction of Mathematical Concepts: How Does the Integrated Use of Digital Games and Language-Based Teaching Matter? *Front. Psychol.* 13:858442. https://doi.org/10.3389/fpsyg.2022.858442

Shibata, N. (2021). Selected poster presentations from the American Association of Applied Linguistics conference 2021: Japanese university students' lexical diversity development in essay writing through theme-based instruction. *Language Teaching*, *54*(4), 583–586. https://doi.org/10.1017/S0261444821000306

Sridana, N., Alsulami, N.M., Isnawan, M.G., & Sukarma, I.K. (2025). Problem-Solving Based Epistemic Learning Pattern: Optimizing Mathematical Representation Ability of Prospective Teachers and Pharmacists. *Educational Process: International Journal, 14,* e2025021. https://doi.org/10.22521/edupij.2025.14.21

Sukarma, I. K., Isnawan, Muhamad G., Alsulami, Naif M., (2024). Research on Nonroutine Problems: A Hybrid Didactical Design for Overcoming Student Learning Obstacles, *Human Behavior and Emerging Technologies*, 2024, 5552365, 12. https://doi.org/10.1155/2024/5552365

Tabachnick, B. G., & Fidell, L. S. (2019). Using Multivariate Statistics (7th ed.). Pearson.

Tao, Y., Meng, Y., Gao, Z., & Yang, X. (2022). Perceived teacher support, student engagement, and academic achievement: a meta-analysis. *Educational Psychology*, *42*(4), 401–420. https://doi.org/10.1080/01443410.2022.2033168

Uteuliev, N. S., & Madiiarov, N. K. (2022). The possibilities of using new digital technologies in teaching students the course of geometry. *Iasaui Universitetinin Khabarshysy, 2*(124), 243–255. https://doi.org/10.47526/2022-2/2664-0686.20

Vankúš, P. (2021). Influence of Game-Based Learning in Mathematics Education on Students' Affective Domain: A Systematic Review. *Mathematics*, *9*(9), 986. https://doi.org/10.3390/math9090986

Wang, M., Binning, K.R., Del Toro, J., Qin, X., & Zepeda, C.D. (2021). Skill, Thrill, and Will: The Role of Metacognition, Interest, and Self-Control in Predicting Student Engagement in Mathematics Learning Over Time. *Child development*, *92*(4), 1369-1387. https://doi.org/10.1111/cdev.13531

Wang, Z., Rimfeld, K., Shakeshaft, N., Schofield, K., & Malanchini, M. (2020). The longitudinal role of mathematics anxiety in mathematics development: Issues of gender differences and domain-specificity. *J Adolesc, 80*:220-232. https://doi.org/10.1016/j.adolescence.2020.03.003

Wild, S., Rahn, S. & Meyer, T. (2024). Factors mitigating the decline of motivation during the first academic year: a latent change score analysis. *Motiv Emot* **48**, 36–50. https://doi.org/10.1007/s11031-023-10050-1

Yulianto, D., Juniawan, E. A., Junaedi, Y., Anwar, S., & Umami, M. R. (2024). Fostering Mathematical Motivation with Wordwall Media: A Study of the ARCS Model (Attention, Relevance, Confidence, and Satisfaction) Based on Sex Among High School Students. *SJME (Supremum Journal of Mathematics Education)*, *8*(2), 173–196. https://doi.org/10.35706/sjme.v8i2.11186

Yulianto, D., Umami, M., Junaedi, Y., & Anwar, S. (2024). Analysis of Mathematical Literacy among Junior High School Students in Lebak-Banten Regency: A Case Study of PISA-Type Questions Considering Accreditation, School Status, Skill Levels, and Gender. *PAKAR Pendidikan*, *22*(1), 203-232. https://doi.org/10.24036/pakar.v22i1.509

Zeybek, N., & Saygı, E. (2023). Gamification in Education: Why, Where, When, and How? A Systematic Review. *Games and Culture, 19*(2), 237-264. https://doi.org/10.1177/15554120231158625

Zhang, Qi, Yu, L., & Yu, Z. (2021). A Content Analysis and Meta-Analysis on the Effects of Classcraft on Gamification Learning Experiences in terms of Learning Achievement and Motivation, *Education Research International*, 2021, 9429112, 21 pages, 2021. https://doi.org/10.1155/2021/9429112