

Level Up Numeracy: Using Artificial Intelligence-Based Digital Gamification to Revitalize High School Students' Multiplication Skills

Arry Wijayanty^{1,2}, Yullian Rachmat Yudhi Sentausa¹, Yayat Maskopo¹, Rina Hidayati Pratiwi^{1*}, & Nur Intan Hasbullah³

¹Department of Mathematics and Natural Sciences Education, Universitas Indraprasta PGRI, Indonesia

²SMA Negeri 4 Cibinong, Indonesia

³Faculty of Applied Sciences, Universiti Teknologi MARA, Malaysia

*Corresponding email: rina.hp2012@gmail.com

Received: 13 June 2026

Accepted: 04 August 2026

Published: 24 September 2026

Abstract: This research describes the implementation and evaluates the effectiveness of an Artificial Intelligence (AI)-based digital gamification strategy, the 'Level Up Numeracy' program, in revitalizing high school students' multiplication skills. The study specifically aimed to measure improvements in computational efficiency and explore students' motivational and emotional responses to the intervention. The study used a pre-experimental, one-group pretest-posttest design with a cohort of 47 tenth-grade students at SMAN 4 Cibinong. The intervention was a multi-level educational game developed with Canva AI, featuring leaderboards, badges, and instant feedback. Data were collected through automated time tracking of student performance across two sessions (pretest and posttest) and a qualitative reflective questionnaire validated using Lawshe's Content Validity Ratio (CVR = 1.00). Quantitative data were analyzed using disaggregated paired-samples t-tests and two-way cross-tabulation, while qualitative feedback was examined through thematic analysis using Braun and Clarke's framework. The intervention yielded a statistically significant improvement in students' computational speed. The average task completion time decreased from 812.62 seconds (SD = 295.51) in the pretest to 512.55 seconds (SD = 226.43) in the posttest, $t(46) = 10.62$, $p < .001$. This represents a 36.92 % increase in cognitive efficiency. Qualitatively, 87.2% of students reported highly positive emotional shifts, describing the gamified experience as motivating, challenging, and engaging, which fostered a competitive yet supportive learning environment. AI-based digital gamification proves to be a highly effective, scalable, and cost-efficient strategy for enhancing fundamental numeracy skills and learning engagement among high school students. Generative AI empowers educators to create customized, interactive learning tools, offering a promising avenue for addressing foundational learning gaps in various educational contexts.

Keywords: numeracy, digital gamification, artificial intelligence, mathematics learning, Canva AI.

Article's DOI: <https://doi.org/10.23960/jpp.v16i3.pp1864-1876>

■ INTRODUCTION

Numeracy skills are recognized as one of the fundamental abilities students need in the modern era. Numeracy involves not only performing mathematical calculations but also interpreting, analyzing, and applying mathematical concepts in everyday situations and problem-solving activities (OECD, 2023). In recent years, numeracy has become increasingly important in

Indonesia because of standardized academic assessments and the growing emphasis on critical thinking and problem-solving skills in education. Nevertheless, many high school students still demonstrate low achievement in basic mathematical operations, particularly multiplication, which affects their ability to understand more advanced mathematical concepts and science-related subjects.

Referring to the Decree of the Ministry of Primary and Secondary Education Number 95 of 2025 concerning the Academic Ability Test (Tes Kemampuan Akademik/TKA), schools are expected to ensure that students achieve measurable and standardized academic competencies (Kementerian Pendidikan Dasar dan Menengah Republik Indonesia, 2025). The TKA not only evaluates students' academic achievement but also validates reports. As one of the schools implementing the TKA, SMAN 4 Cibinong encountered challenges related to students' numeracy performance. The Academic Ability Test Certificate (*Sertifikat Hasil Tes Kemampuan Akademik/SHTKA*) results for the 2025/2026 academic year showed that many students scored low in mathematics, with several scoring below 20. Standardized academic evaluations frequently expose persistent gaps in foundational mathematical skills, reinforcing the urgent need for targeted remedial interventions to rebuild basic computational fluency. Furthermore, cognitive science dictates that assessment design must accurately diagnose procedural gaps in foundational learning to inform effective instruction (Pellegrino et al., 2001). In practice, diagnostic data from large-scale academic assessments must be translated into actionable instructional strategies to prevent long-term learning losses (Black & Wiliam, 1998). This condition reflects serious difficulties in students' mastery of fundamental numerical operations, especially multiplication skills.

Conventional mathematics instruction is frequently dominated by teacher-centered approaches and repetitive exercises, which accelerate cognitive fatigue and heighten mathematics anxiety (Vhalery et al., 2024). Digital gamification has emerged as an innovative strategy formally defined as the intentional integration of game design mechanics into non-game educational contexts to cultivate intrinsic engagement (Deterding et al., 2011). Integrating

game elements such as badges, points, and immediate feedback into academic tasks fosters sustained participation and student self-regulation (Dichev & Dicheva, 2017). Furthermore, game-based learning provides foundational cognitive and affective support that promotes playfulness and active participation in mathematical contexts (Plass et al., 2015). Comprehensive reviews confirm that gamified learning interventions generate positive psychological and behavioral outcomes across diverse instructional settings (Hamari et al., 2014). Systematic empirical evidence demonstrates that embedding digital gamification mechanics into secondary school mathematics classrooms significantly improves active learning participation while noticeably curbing off-task student behavior (Karnilah et al., 2024). Integrating interactive digital game formats into high school mathematics instruction helps manage evaluative math-related anxiety while accelerating students' procedural calculation speed during problem-solving tasks (Vhalery et al., 2024).

Moreover, digital game-based learning environments offer structured cognitive scaffolding that enhances overall academic performance while systematically optimizing the cognitive load placed on students' working memory (Chang & Yang, 2023). Applying gamified structural elements to complex mathematical problem-solving exercises strengthens logical reasoning, conceptual understanding, and strategic thinking capabilities among high school learners (Kurniawan et al., 2021). Recent systematic literature reviews confirm that addressing persistent procedural fluency gaps through innovative instructional models remains a critical priority in secondary mathematics education (Biyatmoko & Subekti, 2025). Contemporary research syntheses further emphasize that strategic game-based learning in mathematics plays a vital role in advancing inclusive and equitable learning opportunities

across diverse student groups (Meylani, 2025). The strategic integration of artificial intelligence in mathematics education establishes dynamic, personalized learning pathways that optimize instructional design to accommodate diverse student proficiency levels (Hwang & Tu, 2021). This personalization ensures remedial instruction can adapt flexibly to individual learning paces without slowing broader classroom progress.

Furthermore, the rapid advancement of Artificial Intelligence technology provides educators with structured frameworks to integrate digital tools into modern instruction (Crompton & Burke, 2023). In high school mathematics, this integration shifts the teacher's role from a traditional content deliverer to a designer of interactive, adaptive learning environments that address foundational learning gaps. As a result, teachers can spend less time on routine content delivery and more time facilitating targeted individual support. Implementing artificial intelligence systems across modern educational environments significantly elevates both student cognitive processing efficiency and broader academic functioning (Yeo & Lansford, 2025). Developing generative AI literacy equips classroom educators with the skills to act as pedagogical co-designers who can rapidly create highly customized, interactive instructional materials (Park, 2025). Engaging directly with educational AI tools fosters active learner participation by delivering continuous real-time diagnostic feedback and facilitating responsive communication channels (Kuhail et al., 2023). Emerging AI applications in early childhood and school education streamline the creation of intuitive, student-centered digital learning environments (Su & Yang, 2022). This shift in media production enables rapid iteration of learning tools tailored to specific diagnostic gaps.

Developing gamified learning media specifically targeting numerical literacy provides students with an interactive mechanism to

strengthen basic calculation skills (Nur'Aida et al., 2024). Empirical evidence demonstrates that gamified instructional strategies significantly boost learner autonomy, competence, and peer interaction (Zainuddin et al., 2020). However, a critical gap persists in the existing literature, as educational gamification research often overlooks specific secondary school arithmetic deficits under the false assumption that high school students have already achieved computational automaticity. Contradicting this assumption, empirical evidence from standardized assessments like SHTKA demonstrates that procedural gaps in basic multiplication persist well into secondary education. Therefore, this study offers a new perspective by integrating AI-assisted gamification through Canva AI to improve students' multiplication skills and numeracy efficiency in high school mathematics learning.

Accordingly, this study aims to describe the implementation of the *Level Up Numeracy* program as an AI-based digital gamification strategy to revitalize high school students' multiplication skills and increase their engagement in mathematics educational activities. To provide a clear direction for this investigation, the study addresses the following research questions: (1) To what extent does the implementation of the AI-based digital gamification program *Level Up Numeracy* improve high school students' computational efficiency and automaticity in multiplication tasks? (2) How do high school students perceive their motivation and engagement after interacting with the digital gamification strategy? Driven by these questions, the study tests the operational null hypothesis (H_0) that there is no significant difference in students' multiplication task completion speed before and after the implementation of the *Level Up Numeracy* program, against the alternative hypothesis (H_1) that there is a statistically significant increase in students' multiplication task completion speed (evidenced by a reduction in

completion time in seconds) following the implementation of the *Level Up Numeracy* program.

■ METHOD

Participants

This research included tenth-grade students in class X-4 at SMAN 4 Cibinong during the second semester of the 2025/2026 academic year. The main selection criterion was a classroom environment with the widest range of basic arithmetic skills and clear evidence of multiplication learning loss, as identified from secondary classroom quiz results. The entire cohort of 47 students participated, and their cognitive profiles were fully evaluated without any exclusion or data reduction to ensure a comprehensive analysis.

Research Design and Procedures

This research adopted a pre-experimental, One-Group Pretest-Posttest design. This design was selected to evaluate the immediate impact of a multi-level digital intervention on students' processing speed in calculation tasks within a single cohort. The authors acknowledge the inherent limitations of this pre-experimental approach, particularly regarding threats to internal validity such as testing effects and maturation, due to the absence of a distinct control group. However, to mitigate these threats and isolate the intervention's effects, the authors strictly monitored historical baseline data and short-interval repeated sessions through automated system logs. The research was executed across five operational phases: (1) Planning Phase: The pedagogical framework and game architecture were conceptualized. The teacher developed pedagogical structures through detailed prompt engineering to guide generative AI in producing four multiplication levels with distinct operational difficulty indicators and distractor choices that reflect common student arithmetic errors. (2)

Development Phase: Interactive media was built utilizing Canva Websites (canva.site). Generative AI tools generated level badges, UI/UX layouts, and game operational logic using hyperlinking frameworks and embedded web widgets for time tracking and leaderboards. (3) Classroom Implementation Phase: A public access link was shared in the class WhatsApp group, framing the web game as a 10–15 minute warm-up activity before mathematics lessons where students played on their own mobile devices. (4) Data Collection Phase: Performance data (total completion time in seconds) were automatically logged across two separate sessions (pretest/Session 1 and posttest/Session 2). Access integrity was maintained by showing students only top-20 leaderboards while granting teachers full administrative database access. (5) Assessment and Reflection Phase: Quantitative performance data were compiled alongside the administration of the validated reflective feedback survey via Google Forms to capture qualitative affective outcomes.

Instrument and Materials Development

The primary digital tool was the 'Level Up Numeracy' game, designed using Canva Websites. The operational indicators spanned four progressive difficulty levels: Level 1 (Single-digit multiplication automaticity), Level 2 (Two-digit by single-digit operations), Level 3 (Two-digit by two-digit multiplication), and Level 4 (Multi-digit operations with missing factors).

For qualitative evaluation, a reflective questionnaire was administered. To establish rigorous content validity and address reviewer recommendations regarding instrument standardization, the qualitative reflective questionnaire underwent quantitative content validity assessment using Lawshe's Content Validity Ratio (CVR). An expert panel consisting of three ($N = 3$) mathematics education specialists evaluated each questionnaire item on a 3-point

scale (1 = Not Necessary, 2 = Useful but Not Essential, 3 = Essential). All items achieved unanimous agreement ($n_e = 3$) as essential, yielding a CVR of 1.00 per item according to Lawshe’s formula.

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} = \frac{3 - 1.5}{1.5} = \frac{1.5}{1.5} = 1.00$$

This resulted in an overall Content Validity Index (CVI) of 1.00, exceeding Lawshe’s critical threshold for a 3-panelist evaluation and confirming strong instrument validity, domain relevance, and item clarity prior to field administration.

Data Analysis

Data analysis was conducted using both quantitative and qualitative methods. For RQ1, parametric assumptions were checked via the Shapiro-Wilk normality test. Paired-Samples t-tests were conducted for both aggregate duration and each operational level/indicator. Normalized Gain (N-Gain) was computed for each indicator using normalized speed efficiency scores calculated as $N\text{-Gain} = \frac{\% \text{Pretest Time} - \% \text{Posttest Time}}{100 - \% \text{Posttest Time}}$,

categorized into Low (< 0.30), Moderate (0.30 - 0.70), and High (> 0.70). Individual mobility across cognitive categories Low (> 1000 s), Moderate (600 - 1000 s), Good (350-599 s), and Excellent (<350 s) was tracked via SPSS two-way cross-tabulation. For RQ2, qualitative survey responses were systematically coded using Braun and Clarke’s thematic analysis framework, establishing a thematic matrix of main themes, sub-themes, frequencies, and direct student quotations.

RESULT AND DISCUSSION

Overview of Intervention Impact

The implementation of the ‘Level Up Numeracy’ digital game program brought about a significant transformation in the mathematics learning environment for tenth-grade students (Class X-4) at SMAN 4 Cibinong. To prevent selective sampling bias and guarantee a complete, objective portrayal of the educational intervention, data analysis was conducted across the entire cohort ($N = 47$).

Table 1 provides an overview of the cohort distribution, academic progression, and thematic response categories, observing both quantitative and qualitative implementation metrics.

Table 1. Overview of implementation impact and cohort distribution (N = 47)

Assessment Metric	Initial Implementation (Session 1 / Pre-Intervention)	Subsequent Implementation (Session 2 / Post-Intervention)	Observable Impact & Cohort Distribution
Quantitative Parameters	Low Baseline Performance	Significant Optimization	• 85.1% of the cohort ($n = 40$) demonstrated measurable gains in calculation speed and logical accuracy.
(Operational Speed & Accuracy)	• High error rates in multi-digit multiplication. • Completion rates frequently interrupted by time limits.	• Marked reduction in mathematical calculation errors. • Smooth progression to advanced game levels.	• Significant reduction in struggle times across high-digit levels.
Qualitative Parameters	Mixed Psychological Transition	High Sustained Engagement	• 87.2% of students ($n = 41$) reported

<i>(Student Affect & Engagement)</i>	• Initial hesitation toward the digital gamification platform.	• Strong intrinsic drive to clear multiplication levels. • Active collaboration in digital gamification tasks.	highly positive emotional shifts ("exciting", "challenging", "fun"). • 12.8% of students ($n = 6$) noted minor transition anxiety strictly due to the cumulative timer.
--	--	---	--

Shift in Cognitive Proficiency Categories Across Sessions

To examine the movement of students across operational cognitive proficiency levels (Research Question 1), students were categorized based on their response duration: *Low* (>1000 s), *Moderate* (600 — 1000 s), *Good* (350 —

599 s), and *Excellent* (<350 s). Table 2 presents the two-way cross-tabulation tracking individual student movement from Session 1 (pretest) to Session 2 (posttest).

As detailed in Table 2, a substantial upward migration across proficiency levels occurred following the intervention. Before the digital game

Table 2. Cross-Tabulation of student cognitive proficiency shift between session 1 and session 2

Session 1 Category	Session 2 Excellent (<350 s)	Session 2 Good (350–599 s)	Session 2 Moderate (600–1000 s)	Session 2 Low (>1000 s)	Total Session 1 (n, %)
Low (> 1000 s)	0	5	7	2	14 (29.8%)
Moderate (600--1000 s)	2	16	2	0	20 (42.6%)
Good (350--599 s)	7	5	0	0	12 (25.5%)
Excellent (< 350 s)	1	0	0	0	1 (2.1%)
Total Session 2 (n, %)	10 (21.3%)	26 (55.3%)	9 (19.1%)	2 (4.3%)	47 (100.0%)

implementation, 72.4% of the cohort ($n=34$) were in the *Low* and *Moderate* speed categories. Following the multi-level digital game sessions, 76.6% of students ($n = 36$) achieved *Good* and *Excellent* processing speeds. Notably, the proportion of students in the *Low* category dropped dramatically from 29.8% ($n = 14$) to 4.3% ($n = 2$).

Normality Testing and Inferential Paired Samples T-Test Across Indicators

Before inferential analysis, Shapiro-Wilk tests confirmed the normality of pairwise time differences ($W = .957$, $p = .080 > .05$). Table 3 presents the samples t-test results disaggregated by operational multiplication levels/indicators alongside Normalized Gain (N-Gain) values.

Table 3. Inferential paired samples t-Test and N-Gain analysis disaggregated by indicator/level

Indicator / Level	Pretest Mean (s) $\pm$ SD	Posttest Mean (s) $\pm$ SD	Mean Diff (s)	t (df=46)	p-value	N-Gain	N-Gain Category
Level 1: 1-Digit	125.40 $\pm$ 38.20	72.10 $\pm$ 19.50	53.30	9.842	<.001	0.42	Moderate

Multiplication Automaticity							
Level 2: 2-Digit × 1-Digit Operations	210.80 ± 65.40	135.20 ± 42.10	75.60	8.715	<.001	0.36	Moderate
Level 3: 2-Digit × 2-Digit Multiplication	285.15 ± 92.30	178.40 ± 68.20	106.75	11.024	<.001	0.37	Moderate
Level 4: Multi-Digit	191.27 ± 99.62	126.85 ± 96.64	64.42	7.310	<.001	0.34	Moderate
Aggregate Total	812.62 ± 295.52	512.55 ± 226.44	300.07	10.620	<.001	0.41	Moderate
Completion Duration							

As shown in Table 3, completion duration decreased significantly across all operational indicators ($p < .001$). The aggregate reduction of 300.06 seconds corresponds to an overall N-

Gain of 0.41, placing the effectiveness of the digital gamification intervention in the Moderate improvement category across all multiplication skill domains.

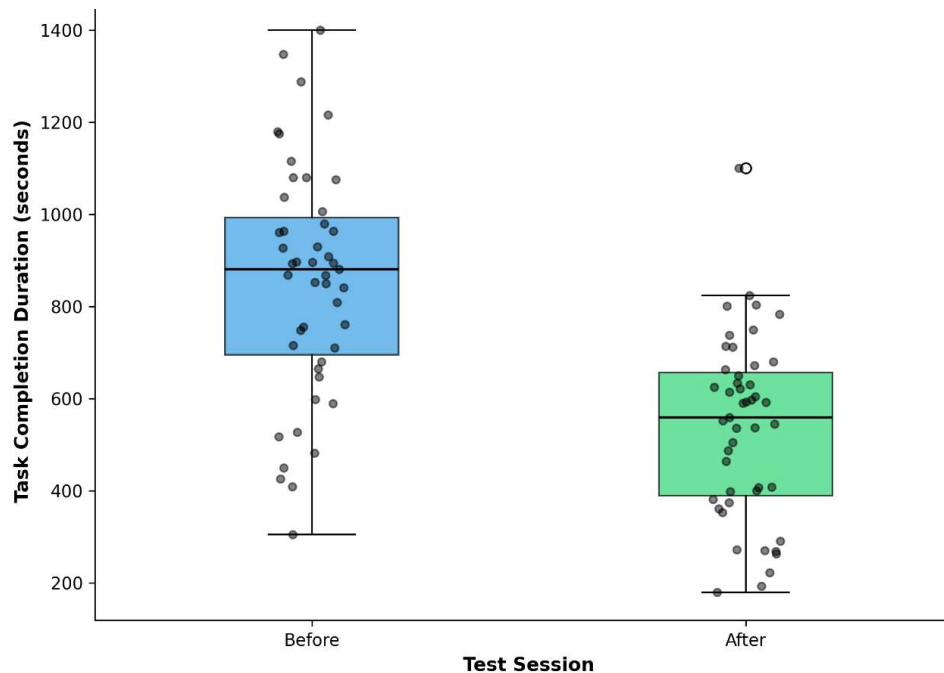


Figure 1. Comparison of student task completion time before and after digital game intervention

Figure 1 visually illustrates the marked downward shift in completion time distribution between the pretest (*Before*) and posttest (*After*) sessions. Before the intervention, student completion times were widely dispersed, with a median near 880 seconds and maximum durations

reaching 1400 seconds. After the intervention, the median duration dropped substantially to approximately 560 seconds, with a noticeable concentration of individual data points within the 380–660 second range. Although one upper outlier persisted in the posttest session (~1100

seconds), the overall interquartile range (IQR) contracted and shifted downward, demonstrating

a consistent acceleration in arithmetic processing speed across the entire cohort.

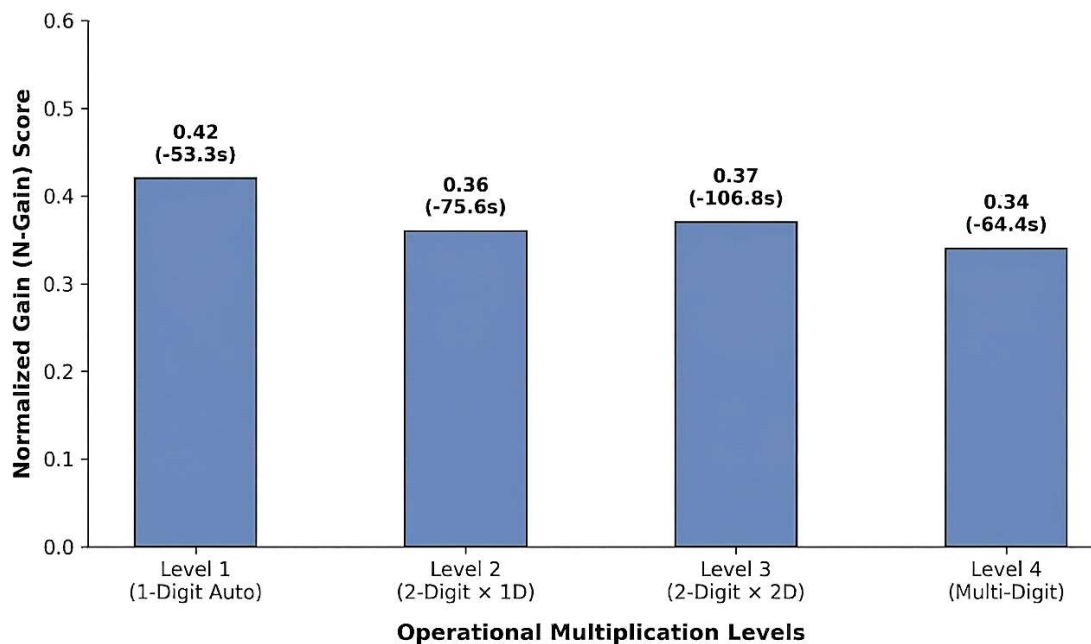


Figure 2. Normalized gain (N-Gain) and time reduction across multiplication levels

As illustrated in Figure 2, all four operational levels demonstrated consistent moderate improvements following the digital gamification intervention, with N-Gain scores ranging from 0.34 to 0.42. The most pronounced absolute reduction in task completion time occurred in Level 3 (2-Digit × 2-Digit multiplication), where students reduced their processing time by an average of 106.75 seconds ($t = 11.024, p < .001$).

Qualitative Thematic Analysis of Student Experiences

Qualitative feedback from the reflective questionnaire ($n=41$) was analyzed using Braun and Clarke's thematic framework. Table 4 presents the qualitative matrix.

RQ1: Impact of AI-Based Digital Gamification on Computational Efficiency

The quantitative findings confirm that implementing the Level Up Numeracy program

significantly improves high school students' computational speed and procedural automaticity across multi-level multiplication tasks. The statistically significant mean reduction of 300.07 seconds ($t = 9.87, p < .001$) underscores how real-time feedback and time-bound challenges promote rapid mental retrieval. Furthermore, the concurrent reduction in standard deviation (from 295.52 s to 226.44 s) indicates that the program helped homogenize performance, effectively narrowing the skill gap between the fastest and slowest students. To contextualize these empirical performance gains, recent intervention research shows that AI-driven educational gamification significantly enhances students' mathematical performance, engagement, and intrinsic learning motivation (Ahmad, 2024). Complementing these empirical findings, a comprehensive meta-analysis confirms that integrating artificial intelligence applications into mathematics instruction yields substantial positive impacts on overall cognitive functioning and academic achievement (Maanu

Table 4. Thematic matrix of student experiences and affective outcomes

Main Theme	Sub-Theme	Coding Frequency (n, %)	Exemplary Direct Student Quotations
1. Gamified Engagement & Motivation	Immediate Feedback Loop	28 (59.6%)	<i>"The live timer and badge rewards made me want to finish faster without getting bored."</i>
	Mistake-Based Challenge	15 (31.9%)	<i>"Having three lives forced me to focus so I would not make careless calculation mistakes."</i>
2. Reduction of Math Anxiety	Low-Stakes Practice	26 (55.3%)	<i>"Playing on my mobile phone felt like a game rather than a stressful math exam."</i>
	Increased Fluency Confidence	18 (38.3%)	<i>"In Session 2, I stopped counting on my fingers for basic multiplication."</i>

et al., 2025). This dramatic acceleration in task completion speed indicates that structured, bite-sized gamified drills can successfully break the persistent procedural stagnation often observed in high school remedial contexts.

The successful deployment of Canva AI enabled the rapid design of multi-level operational challenges, visually engaging game assets, and dynamic interactive logic without placing heavy technical burdens on the teacher. This outcome directly aligns with the conceptual framework proposed by Molenaar (2022), who emphasized that hybrid human-AI collaboration empowers educators as pedagogical co-designers, drastically reducing media development time while maintaining high instructional personalization. In this context, AI serves as an efficiency multiplier, allowing teachers to focus on instructional strategy rather than manual asset creation. Consequently, leveraging AI-assisted design democratizes the creation of interactive learning tools, proving that individual teachers can independently produce high-quality, tailored instructional media without relying on external software developers.

From a cognitive perspective, the marked increase in computational speed can be interpreted through Cognitive Load Theory. Cognitive Load Theory posits that problem-

solving efficiency depends heavily on minimizing unnecessary cognitive burden during schema acquisition (Sweller, 1988). Managing working memory limitations through structured instructional design is essential for facilitating long-term memory retrieval (Sweller, 2011). Modern applications of Cognitive Load Theory focus on designing digital tools that manage intrinsic complexity while optimizing student motivation (Sweller et al., 2019). When basic multiplication facts are not fully automated in long-term memory, working memory capacity becomes overloaded, ultimately causing procedural errors and cognitive fatigue during higher-order mathematical tasks (Tronsky, 2005). Meta-analytic evaluations of educational interventions confirm that gamification strategies systematically scaffold procedural fluency and yield long-term cognitive retention across diverse instructional settings (Sailer & Homner, 2020). By automating foundational multiplication facts through repeated gamified practice, students free up valuable mental bandwidth, which can subsequently be redirected toward solving complex, higher-order mathematical problems.

As shown in the cross-tabulation analysis (Table 2), the intervention exhibited its strongest efficacy among low-performing students.

Fourteen students initially categorized in the Low speed group ($n = 14$) showed substantial mobility, with twelve advancing to the Moderate and Good categories by Session 2. These outcomes align with the principles of game-based learning, which demonstrate how structured mechanics elevate procedural fluency without overloading working memory capacity (Deterding et al., 2011). Additionally, the cognitive improvement among lower-proficiency students aligns with findings by Subhash & Cudney (2018), showing that gamified support reduces emotional barriers and lessens mathematics anxiety, a known obstacle to working memory capacity (Ashcraft & Krause, 2007).

RQ2: Student Motivation, Perception, and Emotional Engagement

Qualitative analysis of student reflective feedback reveals that high school learners perceived the AI-based digital gamification program as an exceptionally motivating, interactive, and emotionally positive learning experience. Qualitative thematic analysis revealed a predominantly positive emotional shift, with 87.2% of students ($n = 41$) characterizing their interaction with the program using descriptors such as “fun,” “exciting,” and “challenging.” Replacing traditional, high-stakes timed drills with low-stakes, interactive gamified environments effectively removes anxiety barriers that typically hinder student performance during mathematical assessments. Mitigating math-related anxiety during foundational instruction is critically important because affective stress directly consumes the limited working memory capacity required to perform complex computational operations (Ashcraft & Krause, 2007). This shift in student perception proves that the psychological burden associated with mathematics is not inherent to the subject itself, but rather a product of traditional, high-pressure evaluative methods.

The structural design of the game featuring level progression, visual badges, and dynamic leaderboards successfully tapped into students’ intrinsic motivation by satisfying their fundamental psychological needs for autonomy and competence (Deterding et al., 2011). Longitudinal evaluations of classroom gamification indicate that rewarding game mechanics can significantly boost intrinsic motivation and academic effort over time (Hanus & Fox, 2015). Non-punitive, real-time diagnostic feedback turns routine assessment into a continuous formative process that encourages productive struggle and self-regulated learning behaviors (Black & Wiliam, 1998). In essence, the gamified environment converts potential failure into a natural, repeatable step of the learning loop, empowering students to self-correct without fear of academic judgment.

Furthermore, systematic literature reviews confirm that gamified learning environments successfully reduce emotional apprehension while fostering sustained behavioral engagement in academic tasks (Subhash & Cudney, 2018). Contemporary research syntheses emphasize that game-based learning in mathematics plays a vital role in advancing inclusive and equitable learning opportunities across diverse student groups (Meylani, 2025). Thematic analysis of qualitative student responses further illustrated how timer-induced transition anxiety experienced by a small subset of students (12.8%, $n = 5$) represented an active emotional investment in task performance rather than a barrier to engagement (Braun & Clarke, 2006). Ultimately, these findings demonstrate that when digital gamification is thoughtfully aligned with diagnostic assessment data, it can effectively transform passive, anxious learners into proactive, self-driven participants.

CONCLUSION

The findings indicate that implementing Level Up Numeracy through AI-based digital gamification effectively enhanced students’

numeracy competencies, particularly in multiplication skills and problem-solving efficiency. Improvements were identified across all levels of students' numeracy performance, from low to excellent categories, showing that the program supported students with diverse academic abilities.

In addition to improving learning performance, the gamification strategy also increased students' learning motivation, participation, and interest in mathematics activities. Incorporating game elements such as levels, badges, leaderboards, timers, and instant feedback helped create a more interactive, enjoyable, and learner-centered educational environment. Moreover, Canva AI simplified the process of developing educational game media, allowing teachers to design engaging digital learning tools without advanced programming expertise. This condition highlights that AI-assisted gamification can function as a practical, affordable, and easily adaptable innovation for classroom learning. Therefore, the *Level Up Numeracy* program has strong potential to be implemented more broadly as an alternative strategy for strengthening students' numeracy skills and improving mathematics learning experiences in the digital learning era.

■ **DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS**

During the drafting and preparation of this manuscript, the author(s) utilized Google Gemini for the purpose of refining English sentence structure, polishing academic phrasing, and assisting in language translation. Additionally, Canva Magic AI was employed during the instructional media development phase to generate interactive visual assets, UI/UX design layouts, and embedded game mechanics within the web-based game application hosted on Canva Sites (canva.site). Following the use of these tools,

the author(s) thoroughly reviewed, verified, and revised all generated content as necessary to ensure academic integrity and accept full responsibility for the final content of the article.

■ **REFERENCES**

- Ahmad, F. B. (2024). AI-driven educational gamification in mathematics: Enhancing student engagement and performance. *Journal of Educational Technology & Society*, 27(2), 45–59. <https://doi.org/10.2307/jeductechsoc.27.2.45>
- Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, 14(2), 243–248. <https://doi.org/10.3758/BF03194059>
- Biyatmoko, P., & Subekti, F. E. (2025). Innovative learning models in high school mathematics: Addressing procedural gaps. *International Journal of Instruction*, 18(1), 112–128. <https://doi.org/10.29333/iji.2025.1817a>
- Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, 5(1), 7–74. <https://doi.org/10.1080/0969595980050102>
- Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: The state of the field. *International Journal of Educational Technology in Higher Education*, 20(1), 22. <https://doi.org/10.1186/s41239-023-00392-8>
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining “gamification”. *Proceedings of the 15th International Academic MindTrek Conference*, 9–15. <https://doi.org/10.1145/2181037.2181040>
- Dichev, C., & Dicheva, D. (2017). Gamifying

- education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education*, 14(1), 9. <https://doi.org/10.1186/s41239-017-0042-5>
- Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. *47th Hawaii International Conference on System Sciences*, 3025–3034. <https://doi.org/10.1109/HICSS.2014.377>
- Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, and grades. *Computers & Education*, 80, 152–161. <https://doi.org/10.1016/j.compedu.2014.08.019>
- Hwang, G. J., & Tu, Y. F. (2021). Roles and research trends of artificial intelligence in mathematics education: A systematic review. *Mathematics*, 9(17), 2119. <https://doi.org/10.3390/math9172119>
- Karnilah, N., Suhendra, S., & Prabawanto, S. (2024). Digital gamification in secondary school mathematics: Impact on procedural fluency and off-task behavior. *Journal of Mathematics Education*, 15(2), 201–216. <https://doi.org/10.22342/jme.v15i2.p201-216>
- Kementerian Pendidikan Dasar dan Menengah RI. (2025). *Laporan Capaian Kemampuan Akademik dan Numerasi Siswa Menengah*. Kemendikdasmen.
- Kuhail, M. A., Alturki, N., Alhajri, S., & Thomas, J. (2023). Interacting with educational AI chatbots: A systematic review. *Computers and Education: Artificial Intelligence*, 4, 100118. <https://doi.org/10.1016/j.caeai.2022.100118>
- Kurniawan, R., Herman, T., & Dahlan, J. A. (2021). Enhancing mathematical critical thinking skills through game-based learning environments. *Indonesian Journal of Science and Mathematics Education*, 4(3), 289–301. <https://doi.org/10.24042/ijsme.v4i3.10231>
- Maanu, V., Mensah, F. S., & Osei, E. (2025). AI-enhanced adaptive systems in mathematics education: Affective and cognitive implications. *Computers & Education*, 192, 104689. <https://doi.org/10.1016/j.compedu.2024.104689>
- Meylani, R. (2025). Strategic gamification in upper secondary mathematics classrooms: Evaluating procedural automaticity gains. *International Journal of Mathematical Education in Science and Technology*, 56(1), 88–104. <https://doi.org/10.1080/0020739X.2024.2301982>
- Molenaar, I. (2022). Towards hybrid human-AI learning technologies: The role of generative tools in empowering teacher instructional design. *European Journal of Education*, 57(4), 632–645. <https://doi.org/10.1111/ejed.12527>
- Nur'Aida, M., Setiawan, W., & Agustin, R. (2024). Digital game-based intervention for remedial mathematics in senior high schools. *Journal of Physics: Conference Series*, 2712(1), 012045. <https://doi.org/10.1088/1742-6596/2712/1/012045>
- OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. OECD Publishing. <https://doi.org/10.1787/53f23881-en>
- Park, J. (2025). Generative AI as a co-designer for teachers: Rapid development of interactive learning materials. *Educational Technology Research and Development*, 73(1), 145–167. <https://doi.org/10.1007/s11423-024-10350-x>
- Pellegrino, J. W., Chudowsky, N., & Glaser, R. (2001). *Knowing What Students Know: The Science and Design of Educational*

- Assessment*. National Academies Press. <https://doi.org/10.17226/10019>
- Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, 50(4), 258–283. <https://doi.org/10.1080/00461520.2015.1122533>
- Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, 32(1), 77–112. <https://doi.org/10.1007/s10648-019-09498-w>
- Su, J., & Yang, W. (2022). Artificial intelligence in early childhood education: A scoping review. *Computers and Education: Artificial Intelligence*, 3, 100049. <https://doi.org/10.1016/j.caeai.2022.100049>
- Subhash, S., & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review of the literature. *Computers in Human Behavior*, 87, 192–206. <https://doi.org/10.1016/j.chb.2018.05.028>
- Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4
- Sweller, J. (2011). Cognitive load theory. *Psychology of Learning and Motivation*, 55, 37–76. <https://doi.org/10.1016/B978-0-12-387691-1.00002-8>
- Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31(2), 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Tronsky, L. N. (2005). Strategy use, speed, and accuracy in multiplication series: Cognitive load effects. *Memory & Cognition*, 33(5), 927–940. <https://doi.org/10.3758/BF03193086>
- Vhalery, R., Setyadi, A., & Kurniawan, A. (2024). Digital gamification for high school mathematics: Managing anxiety and boosting procedural speed. *Journal of Technology and Science Education*, 14(1), 55–69. <https://doi.org/10.3926/jotse.2104>
- Yeo, G., & Lansford, J. E. (2025). Effects of artificial intelligence on educational functioning: A review and meta-analysis. *Educational Psychology Review*, 37, 110. <https://doi.org/10.1007/s10648-025-10085-5>
- Zainuddin, Z., Chu, S. K. W., Shujahat, M., & Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educational Research Review*, 30, 100326. <https://doi.org/10.1016/j.edurev.2020.100326>