

Gamified Instructional Modules to Enhance Mathematical Literacy and Math-Specific Grit Among Elementary Students

Rucita Iga Diningrum^{1*}, Poppy Yaniawati²

^{1*,2}Magister Pendidikan Matematika, Universitas Pasundan

Jl. Sumatera No.41, Babakan Ciamis, Kec. Sumur Bandung, Kota Bandung, Indonesia

^{1*}rucitaigadiningrum@gmail.com; ²pyaniawati@unpas.ac.id

(*) corresponding author

ABSTRAK	ABSTRACT
Penelitian ini mengembangkan modul ajar berbasis gamifikasi untuk meningkatkan literasi matematis dan math-specific grit siswa sekolah dasar. Rendahnya literasi matematis siswa Indonesia, sebagaimana ditunjukkan oleh pencapaian PISA dan data nasional, memerlukan alternatif pembelajaran inovatif yang mempertimbangkan aspek afektif seperti kecemasan matematika. Penelitian ini menggunakan desain metode campuran dengan pendekatan kuasi-eksperimental, melibatkan dua kelas intak masing-masing 21 siswa. Modul dikembangkan mengikuti model Borg dan Gall, mengintegrasikan elemen gamifikasi (poin, tantangan, papan peringkat, umpan balik) dengan aktivitas pemecahan masalah kontekstual pada materi pecahan. Implementasi berlangsung selama 12 minggu dengan dua sesi per minggu. Data kuantitatif dikumpulkan melalui tes literasi matematis, skala math-specific grit, dan inventori kecemasan matematika; data kualitatif melalui observasi dan wawancara. Modul dinyatakan sangat layak berdasarkan validasi ahli. Kelompok eksperimental menunjukkan peningkatan literasi matematis dan math-specific grit yang signifikan dibandingkan kelompok kontrol. Peningkatan kedua variabel tidak berbeda berdasarkan tingkat kecemasan siswa. Hubungan positif kuat ditemukan antara literasi matematis dan math-	This study developed a gamification-based teaching module to enhance mathematical literacy and math-specific grit among elementary students. Low mathematical literacy among Indonesian students, as evidenced by PISA scores and national assessments, necessitates innovative instructional alternatives that address affective dimensions such as mathematics anxiety. This research employed a mixed-methods quasi-experimental design involving two intact classes with 21 students each. The module was developed following the Borg and Gall model, integrating gamification elements points, challenges, leaderboards, and feedback with contextual problem-solving activities on fractions. Implementation lasted 12 weeks with two sessions weekly. Quantitative data were collected through mathematical literacy tests, math-specific grit scales, and mathematics anxiety inventories; qualitative data through classroom observations and interviews. The module was rated highly feasible by expert validators. The experimental group demonstrated significantly greater improvements in mathematical literacy and math-specific grit compared to the control group. Both improvements remained consistent across students with varying anxiety levels. A strong positive relationship emerged between mathematical literacy and math-specific grit gains, while mathematics anxiety showed no significant correlation with either

specific grit, sementara kecemasan matematika tidak berkaitan signifikan dengan kedua variabel hasil belajar. Temuan menunjukkan bahwa modul gamifikasi yang dirancang dengan baik menciptakan lingkungan pembelajaran yang mendukung perkembangan kognitif dan afektif siswa, bahkan bagi siswa dengan kecemasan matematika tinggi. Kata Kunci: Desain pedagogis; Kecemasan matematika; Ketekunan; Pemecahan masalah kontekstual; Self-determination theory.	learning outcome. Findings indicate that thoughtfully designed gamification modules create psychologically supportive learning environments fostering both cognitive and affective development, including for students with elevated mathematics anxiety. Keywords: Contextual problem-solving; Mathematics anxiety; Pedagogical design; Perseverance; Self-determination theory.
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RINGKESAN

Panilitian ieu ngembangkeun modul pangajaran dumasar gamifikasi pikeun ningkatkeun literasi matematika jeung ketekunan husus matematika murid sakola dasar. Tingkat literasi matematika anu handap di kalangan murid Indonésia, sakumaha katempo tina hasil PISA jeung data nasional, merlukeun alternatif pangajaran inovatif anu ngémutan aspék afektif saperti kahariwang matematika. Panilitian ieu ngagunakeun desain mixed-methods kalayan pendekatan quasi-eksperimental, ngalibetkeun dua kelas awal anu masing-masing diwangun ku 21 murid. Modul ieu dimekarkeun nurutkeun modél Borg jeung Gall, ngahijikeun unsur gamifikasi (poin, tantangan, papan pamimpin, eupan balik) jeung kagiatan pamecahan masalah kontekstual ngeunaan pecahan. Palaksanaan lumangsung salila 12 minggu kalayan dua sesi per minggu. Data kuantitatif dikumpulkeun ngaliwatan tés literasi matematika, skala ketekunan husus matematika, jeung inventaris kahariwang matematika; data kualitatif dikumpulkeun ngaliwatan observasi jeung wawancara. Modul éta dianggap kacida mungkinna dumasar kana validasi ahli. Kelompok éksperimen nunjukkeun paningkatan signifikan dina literasi matematika jeung ketekunan husus matematika dibandingkeun jeung kelompok kontrol. Peningkatan dina dua variabel éta henteu béda dumasar kana tingkat kahariwang murid. Kapanggih hubungan positif anu kuat antara literasi matematika jeung ketekunan husus matematika, sedengkeun kahariwang matematika henteu signifikan patali jeung salah sahiji variabel hasil diajar. Temuan ieu nunjukkeun yén modul gamifikasi anu dirancang saé nyiptakeun lingkungan diajar anu ngadukung pamekaran kognitif jeung afektif siswa, komo pikeun maranéhna anu gaduh tingkat kahariwang matematika anu luhur.

Kecap konci: Desain pedagogis; Kahariwang matematika; Grit; Pamecahan masalah kontekstual; Teori autodeterminasi.

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1. INTRODUCTION

Mathematical literacy the ability to formulate, employ, and interpret mathematics in authentic contexts has become essential in elementary education, transcending mere computational skills to encompass real-world mathematical reasoning (Supianti et al., 2022; OECD, 2026). Despite international recognition of its importance through programs like PISA, empirical evidence reveals a concerning gap: Indonesian students achieved 364 points in PISA 2025, substantially below the OECD average of 463 points, representing more than five years of learning differential (OECD, 2026; Widayanti et al., 2026). More alarming is stagnation between PISA 2022 and 2025, with no significant improvement despite existing interventions (OECD, 2026). Nationally, more than 30% of Grade 4 students have not achieved expected numeracy competency, indicating that challenges originate in elementary school rather than secondary levels (Kemendikdasmen, 2026; Riyadi et al., 2020). Specific institutional data from SDN 3 Leuwigoong confirm this pattern algebraic domain achievement declined from 71.45 to 60.42/100, while reasoning ability (L3) reached only 57.65/100, demonstrating substantive deficiencies in abstract thinking and high-level problem-solving (Kemdikbud, 2026).

Beyond cognitive deficits, affective factors critically explain low mathematical achievement. Math anxiety feelings of tension, worry, or fear in mathematical contexts (Švecová, 2024; Dewi & Mursitolaksmi, 2020) emerges early, intensifies with age, and creates negative cycles of avoidance and academic failure (Salinas et al., 2022; Radiusman et al., 2025). Research consistently documents strong negative relationships between math anxiety and achievement; anxiety disrupts working memory allocation, undermining both motivation and cognitive processing (Mutlu, 2019; Bjälkebring, 2019; (Lau et al., 2024). Conversely, math-specific grit perseverance and sustained effort amid mathematical challenges functions as a protective factor, enabling students with higher grit to achieve better outcomes even when experiencing elevated anxiety (Yu et al., 2021; Wang et al., 2022). However, this protective mechanism weakens significantly when anxiety remains unaddressed;

students with high math anxiety and low grit succumb to learned helplessness, creating compounding academic deficits (Noh et al., 2026; Aaviste et al., 2026).

Gamification integrating game elements into educational contexts addresses these interconnected cognitive affective challenges by creating low-stakes learning environments where students can attempt, fail, and retry without severe emotional consequences (Syuhada et al., 2023; Fahlevi et al., 2024). Grounded in Self-Determination Theory, gamification fulfills psychological needs for autonomy, competence, and relatedness through reward systems and narratives, thereby enhancing intrinsic motivation (Ryan & Deci, 2000; Ahmmed et al., 2024). Evidence demonstrates that collaborative, interactive gamified modules reduce math anxiety while improving mathematical problem-solving and engagement (Yap & Yew, 2026; Mc Kevitt et al., 2025). Attractive visual design and engaging narratives create non-threatening contexts particularly valuable for elementary students developing initial mathematical associations (Sotirov & Petrova, 2023; Mutua & Obara, 2025). However, gamification's potential only materializes if carefully designed to accommodate students' affective conditions, particularly math anxiety.

Despite growing evidence supporting gamification's effectiveness, substantial research gaps persist. Few studies simultaneously integrate gamified modules with explicit attention to mathematical literacy enhancement and math-specific grit development and math anxiety reduction, particularly at elementary level (Yap & Yew, 2026; Sharma & Dogra, 2026). Fewer still examine math anxiety as a moderating variable affecting intervention outcomes (Noh et al., 2026). Most intervention research focuses on remedial approaches in upper grades, while preventive, developmentally-appropriate interventions in early elementary remain underexplored (Assegaf & Bonyah, 2024; Anugraheni et al., 2025). This research addresses these gaps by developing and testing gamification-based instructional modules designed to simultaneously enhance mathematical literacy and math-specific grit while accounting for students' varying anxiety levels.

This mixed-methods quasi-experimental study addresses five specific research questions: (1) How can gamification-based modules be developed and validated to enhance mathematical literacy and math-specific grit? (2) How do

mathematical literacy levels differ between gamified and conventional instruction, accounting for initial math anxiety? (3) How do math-specific grit levels differ across instructional approaches and anxiety categories? (4) What correlations exist among literacy, grit, and anxiety in both contexts? (5) What is the relative effectiveness of gamified versus conventional instruction? The theoretical framework integrates Self-Determination Theory (explaining motivation enhancement), Cognitive Load Theory (illuminating how emotionally-supportive contexts free cognitive resources), and the protective factor perspective (recognizing math-specific grit as resilience mechanism buffering anxiety effects) (Ryan & Deci, 2000; Yu et al., 2021; Wang et al., 2022).

Key constructs are operationalized as follows: Mathematical Literacy encompasses ability to formulate real-world problems mathematically, employ concepts and procedures, and interpret results, measured via essay-based assessment of fraction concepts (OECD, 2026; Supianti et al., 2022). Math-Specific Grit comprises perseverance of effort and consistency of interest in mathematics, measured via self-report questionnaire (Yu et al., 2021). Math Anxiety comprises emotional reactions (tension, worry, fear) and associated avoidance behaviors, measured via psychometric instrument (Švecová, 2024). Gamification-Based Modules integrate game elements (points, badges, leaderboards, narratives) with pedagogically sound content designed to increase motivation while addressing affective dimensions (Syuhada et al., 2023; Sari et al., 2025).

Theoretically, this research advances understanding of integrated frameworks linking gamification, cognitive achievement, and resilience-building while examining anxiety as a contextual moderator (Sharma & Dogra, 2026). Practically, the study produces a validated, context-specific module adaptable across elementary schools. For students, gamification provides psychologically safe learning fostering confidence and persistence. For teachers, the module offers evidence-based approaches addressing multiple learning dimensions simultaneously. For institutions, successful implementation represents adoptable best practice enhancing mathematics instruction quality (Pratama & Rochmawati, 2019; Sari et al., 2025). Research was conducted at SDN 3 Leuwigoong (Garut District, West Java) using mixed-methods design combining quasi-experimental quantitative

methodology with qualitative inquiry (Yaniawati & Indrawan, 2024; Creswell & Creswell, 2024). This paper subsequently presents Methods (design, participants, instruments, analysis procedures), Results (quantitative findings and qualitative themes), Discussion (interpretation within existing literature), and Conclusion (synthesis and research implications).

2. METHOD

A mixed-methods convergent parallel design was used, combining quantitative quasi-experimental procedures with qualitative inquiry conducted in the same phase. The quantitative strand followed a pretest-posttest nonequivalent control group design within a research and development framework, allowing comparison between gamification-based and conventional instruction. The qualitative strand captured classroom processes through observation, interviews, and document review. Both strands were integrated to obtain a fuller picture of how the module affected mathematical literacy and math-specific grit. This design was appropriate because the study aimed to measure outcomes while also explaining the learning process behind them.

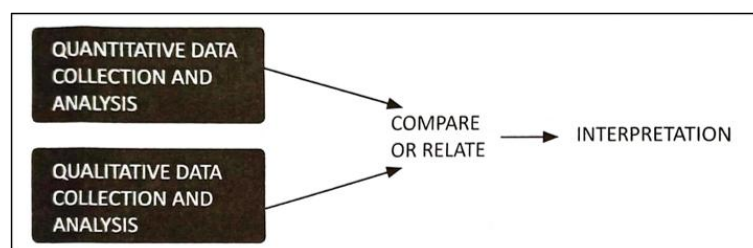


Figure 1. The Convergent Parallel Design

The study involved Grade 4 students at SDN 3 Leuwigoong, Garut District, in the 2026/2027 academic year. Two intact classes were selected purposively on the basis of similar initial achievement, stable class composition, and feasibility of implementation in the school setting. Each class consisted of 21 students, with one class assigned as the experimental group and the other as the control group. Baseline equivalence was checked through pretest scores and relevant class characteristics. This sampling strategy was chosen to preserve natural classroom conditions while keeping the two groups comparable for analysis.

Module development followed the Borg and Gall model through needs analysis, design, validation, revision, and pilot testing. The needs analysis covered classroom observation, curriculum review, and student characterization so the product would match fraction content and elementary learners' developmental level. The module combined game elements such as points, badges, leaderboards, and narratives with activities targeting mathematical literacy and math-specific grit. Expert validation involved subject matter and learning design reviewers who assessed accuracy, pedagogy, and the fit of the gamified structure. After revision, the module was piloted with students outside the sample to refine clarity, engagement, and feasibility before field use.



Figure 2. Borg and Gall Development Model Flow

Three quantitative instruments were used to measure the main variables. Mathematical literacy was assessed with a six-item open-ended test on fraction concepts aligned with formulate, employ, and interpret indicators. Math-specific grit was measured using a 32-item Likert scale covering perseverance of effort and consistency of interest. Math anxiety was measured with a 30-item Likert instrument that captured emotional reactions and avoidance behavior in mathematics. In addition, observation sheets, semi-structured interview guides, student work samples, and classroom photographs were used for qualitative data. All instruments were validated before use, and the quantitative tools had acceptable reliability coefficients.

Table 1. Instrument Specifications

Instrument	Number of Items	Scale/Format
Mathematical Literacy	6 open-ended items	Essay-based; scoring rubric with 4 levels
Math-Specific Grit	32 Likert-type items	5-point Likert scale
Math Anxiety Inventory	30 Likert-type items	5-point Likert scale
Classroom Observation Checklist	18 behavioral indicators	Frequency checklist: 4-point scale
Semi-Structured Interview Guide	10 core questions with 5–7 follow-up probes	Audio-recorded open-ended verbal responses
Student Work Sample Documentation	All completed worksheets, problem-solving sheets, formative assessments, and gamification task outcome	Physical documents & digital scans with student identification codes

Before the main implementation, the quantitative instruments were tried out on students outside the research sample to ensure their validity, reliability, and suitability for elementary learners. The try-out was conducted on 30 students with characteristics similar to the research participants. For the mathematical literacy test, item validity was examined using Pearson Product Moment correlation, while reliability was measured with Cronbach's Alpha. Item discrimination and difficulty indices were also calculated to identify the quality of each problem item and to determine whether revisions were needed before field use. The same procedure was applied to the Math-Specific Grit and Math Anxiety questionnaires, with item validity and internal consistency tested using the same statistical criteria. Based on the try-out results, the instruments showed acceptable psychometric quality and were revised where needed to improve clarity and alignment with the indicators being measured.

Table 2. Summary of Instrument Try-Out Analysis

Instrument	Number of Items	Valid Items	Reliability (α)	Decision
Mathematical Literacy Test	6	6	0.78	Feasible

Instrument	Number of Items	Valid Items	Reliability (α)	Decision
Math-Specific Grit Scale	32	26	0.82	Feasible after revision
Math Anxiety Scale	30	26	0.89	Feasible after revision

The try-out results indicated that the mathematical literacy test met the required validity and reliability standards without item elimination. The Math-Specific Grit and Math Anxiety scales also demonstrated strong internal consistency, although several items were revised to improve clarity and alignment with the constructs measured. These revisions were made on the basis of expert judgment and item analysis, not because the instruments were invalid in substance. All instruments were considered feasible for the main study after refinement.

After the pretest, the experimental class learned with the gamification-based module for 12 weeks, with two sessions per week lasting 70 minutes each, while the control class followed conventional instruction. Classroom observations were carried out throughout the intervention to monitor fidelity and student responses. Interviews with selected students were conducted at weeks 4, 8, and 12 to capture changes in learning experience and perceptions of the module. Work samples and photographs were collected continuously as supporting evidence. At the end of the intervention, the same instruments were administered again as posttests. To keep implementation consistent, both classes received the same timing, environment, and administration procedures.

Quantitative data were first screened with Shapiro-Wilk and Levene tests, followed by baseline equivalence testing. Main analysis used descriptive statistics, normalized gain scores, and two-way ANOVA to examine the effects of instructional model and math anxiety category on mathematical literacy and math-specific grit. When assumptions were not met, Mann-Whitney U tests were applied, and effect sizes were calculated with Cohen's *d*. Pearson correlations were used to examine relationships among the outcome variables within each group. Qualitative data were analyzed through reduction, coding, and thematic interpretation of interview

transcripts and observation notes. The two forms of data were then merged to explain the quantitative results more clearly.

School approval was obtained before the study began, and informed consent was collected from parents while students gave assent to participate. Participation was voluntary, and students could withdraw at any time without penalty. Anonymity was maintained by replacing names with codes, and all data were stored securely for research purposes only. Because random assignment was not possible, the study used intact classes and checked baseline equivalence statistically to support comparability. The single-school setting and modest sample size limit generalization, but the procedures were documented in detail to support replication in similar elementary contexts. Potential issues such as attrition and implementation fidelity were managed through continuous monitoring during the study.

3. RESULT AND DISCUSSION

a. Development and Validation of the Gamification-Based Module

The gamification-based teaching module was developed using the Borg and Gall model, adapted into eight stages: needs analysis, instructional design, initial product development, expert validation, revision, field testing, final revision, and dissemination. The module was designed to support Grade 4 students' mathematical literacy, math-specific grit, and math anxiety in learning fractions. Gamification elements such as points, challenges, rewards, narrative, and feedback were embedded into contextual tasks so that students could engage actively with mathematical ideas while remaining motivated during learning.

Expert validation showed that the module was highly feasible. Material experts rated it at 95.4%, media experts at 94.2%, and language experts at 95.4%, with an overall average of 95.0%. These results indicate that the module was strong in content accuracy, visual design, and linguistic clarity.

Table 3. Validation Results of the Gamification-Based Module

Validator	Mean Score	Percentage	Feasibility
Material expert	4.77	95.4%	Very feasibility
Media expert	4.71	94.2%	Very feasibility
Language expert	4.77	95.4%	Very feasibility
Overall	4.75	95.0%	Very feasibility

The module was revised based on validator feedback, mainly by adding more contextual problems, simplifying some language, improving illustrations, and strengthening scaffolding in interpretation tasks. After revision, the module was considered ready for implementation.

b. Mathematical Literacy

Students in the experimental group showed a larger improvement in mathematical literacy than those in the control group. The experimental group increased from a mean pretest score of 45.48 to a posttest score of 73.62, while the control group increased from 48.67 to 57.90. The normalized gain score also showed a clearer difference, with the experimental group reaching 0.5187, categorized as moderate, and the control group reaching 0.1777, categorized as low.

Table 4. Descriptive Statistics and N-Gain of Mathematical Literacy

Group	Pretest Mean	Posstest Mean	N-Gain	Category
Experimental	45.48	73.62	0.5187	Moderate
Control	48.67	57.90	0.1777	Low

Because the gain data did not fully meet the assumption of normality, the difference was tested using the Mann–Whitney U test. The result showed a significant difference between groups, $U = 0.000$, $Z = -5.547$, $p < .001$.

Table 5. Mann–Whitney U Test for Mathematical Literacy Gain

Variable	U	Z	p-value	Decision
Gain score of mathematical literacy	0.000	-5.547	< 0.001	Significant

c. Math-Specific Grit

A similar pattern was found for math-specific grit. The experimental group increased from 98.38 to 132.76, while the control group increased from 94.48 to 98.29. The N-gain score for the experimental group was 0.5686, categorized as moderate, whereas the control group obtained 0.0591, categorized as low.

Table 6. Descriptive Statistics and N-Gain of Math-Specific Grit

Group	Pretest Mean	Posstest Mean	N-Gain	Category
Experimental	98.38	132.76	0.5686	Moderate
Control	94.48	98.29	0.0591	Low

Since the data were normally distributed but the variances were unequal, the comparison used the independent samples t-test with unequal variances assumed. The result showed a significant difference, $t = 13.726$, $df = 20.697$, $p < .001$.

Table 7. Independent Samples t-Test for Math-Specific Grit Gain

Variable	t	df	p-value	Mean Difference	Decision
Gain score of math-specific grit	13.726	20.697	< 0.001	0.50948	Significant

d. Math Anxiety

Math anxiety scores increased in both groups, but the experimental group showed a larger increase than the control group. The experimental group rose from

89.00 to 109.48, while the control group rose from 88.52 to 94.71. In this instrument, higher scores indicate higher anxiety.

Table 8. Descriptive Statistics of Math Anxiety

Group	Pretest Mean	Posstest Mean
Experimental	89.00	109.48
Control	88.52	94.71

The two groups were statistically equivalent at pretest in terms of math anxiety, with $p = .728$. However, math anxiety did not significantly affect the gain in mathematical literacy or math-specific grit. Neither the main effect of math anxiety category nor its interaction with learning model was significant.

e. Relationship among the Main Variables

Correlation analysis showed a strong and significant positive relationship between mathematical literacy gain and math-specific grit gain, with $r = 0.671$, $p < .001$. In contrast, math anxiety was not significantly related to either mathematical literacy or math-specific grit.

Table 9. Correlation among Main Variables

Relationship	r	p-value	Interpretation
Mathematical literacy and math-specific grit	0.671	< 0.001	Strong, positive, significant
Mathematical literacy and math anxiety	0.223	0.155	Not significant
Math-specific grit and math anxiety	0.096	0.544	Not significant

f. Qualitative Findings

Qualitative analysis of the interviews identified four main themes: positive response to the gamified module, development of mathematical literacy, emergence of math-specific grit, and experiences of math anxiety. Students in the experimental group described the module as more interesting and motivating because of the points, challenges, and visual design. They also reported being more willing to try again when they encountered difficult problems.

Table 10. Main Qualitative Themes

Theme	Main Evidence	Meaning
Positive response to module	Students said the module was fun, attractive, and motivating	Gamification increased engagement
Mathematical literacy	Students mentioned understanding the problem, using strategies, and explaining answers	Learning supported formulate, employ, interpret processes
Math-specific grit	Students reported trying again and not giving up easily	Module encouraged persistence
Math anxiety	Students still feared mistakes, but learning felt safer	Gamification softened anxiety, but did not remove it

Students in the control group, by contrast, described learning more as listening to the teacher, taking notes, and completing exercises. Their responses indicate that the gamified module created a more interactive learning environment that encouraged active problem solving and persistence.

DISCUSSION

The findings show that the gamification-based module was feasible and effective in improving both mathematical literacy and math-specific grit. Its high validation scores suggest that the module was pedagogically sound, visually appropriate, and linguistically suitable for Grade 4 students. This is important because effective learning materials must be aligned with curriculum demands while also being accessible to learners at the intended developmental level (Prastowo, 2018).

The improvement in mathematical literacy suggests that the module helped students engage in the key processes of formulate, employ, and interpret. By using contextual fraction tasks and guided problem-solving activities, the module supported students in making sense of mathematical situations rather than only performing procedures. This is consistent with the view that mathematical literacy involves the ability to use mathematics to understand and solve real-world problems (OECD, 2026; Kolar & Hodnik, 2021).

The increase in math-specific grit indicates that the gamified environment helped students sustain effort when tasks became difficult. Points, challenges, and feedback may have made progress more visible and encouraged students to keep trying. This aligns with grit theory, which defines grit as perseverance and sustained commitment toward long-term goals (Duckworth et al., 2007) . It also supports gamification studies showing that goals, feedback, and rewards can increase engagement and persistence when they are meaningfully connected to learning tasks (Deterding et al., 2011; Tu et al., 2015).

Math anxiety did not significantly affect learning gains, even though anxiety remained present in both groups. This suggests that the module did not eliminate anxiety, but it may have reduced its negative impact by creating a more supportive learning atmosphere. The result is consistent with working memory interference theory, which explains that anxiety can occupy cognitive resources needed for problem solving (Ashcraft & Kirk, 2001). In a less threatening learning context, however, students may still be able to participate and improve. Prior studies also note that game-based learning can support emotional comfort and reduce pressure in mathematics learning (Mc Kevitt et al., 2025; Ng et al., 2022) .

The significant positive correlation between mathematical literacy and math-specific grit suggests that cognitive achievement and productive learning dispositions developed together. Students who were more persistent also tended to improve more in mathematical literacy. This supports the idea that mathematics learning success depends not only on knowledge, but also on the willingness to remain engaged when facing difficulty. Meanwhile, the absence of significant relationships involving math anxiety implies that anxiety alone does not determine learning outcomes when the instructional environment is supportive.

Overall, the module appears to be a promising instructional approach for elementary mathematics. It not only supports achievement, but also helps students develop persistence and engagement in learning. In this sense, gamification functions not as entertainment alone, but as a pedagogical strategy that can improve both cognitive and affective outcomes.

4. CONCLUSION

This study developed and validated a gamification-based teaching module to improve Grade 4 students' mathematical literacy and math-specific grit while examining the role of math anxiety. The module achieved high feasibility through expert validation across content, media, and language dimensions. All research hypotheses were confirmed: the gamified module significantly improved mathematical literacy and math-specific grit compared to conventional instruction; these improvements remained consistent regardless of students' anxiety levels, indicating that anxiety did not determine learning outcomes when supportive learning environments were provided; a strong positive relationship emerged between gains in mathematical literacy and math-specific grit; and math anxiety showed no significant correlation with either outcome variable. Qualitatively, students in the gamified group experienced more engaging and psychologically supportive learning that encouraged active problem-solving and persistence.

Theoretically, the findings reinforce working memory interference theory and self-determination theory by demonstrating that pedagogically aligned gamification simultaneously supports cognitive and affective learning dimensions. Practically, the module offers a validated instructional approach for teachers and schools, suggesting that curriculum developers and policymakers should encourage thoughtful gamification that connects game mechanics meaningfully to learning objectives. However, limitations include the single-school setting, brief implementation period, and reliance on self-report measures for affective constructs. Future research should replicate the module across larger and more diverse samples over extended periods, employ multiple data collection methods, investigate additional psychological mediators and moderators, and examine implementation across diverse mathematics topics and grade levels. Ultimately, the gamification-based module represents a promising, empirically validated instructional approach that creates learning conditions where students, regardless of initial anxiety, can develop stronger mathematical thinking and greater academic resilience, demonstrating that effective gamification transcends entertainment to become a

powerful vehicle for building competence, persistence, and positive dispositions essential for meaningful mathematics learning in elementary education.

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AUTHOR BIOGRAPHY

	Rucita Iga Diningrum, S.Pd. Born in Garut on May 30, 2002, he is a teacher at SDN 3 Leuwigoong, Garut, who graduated with honors from his undergraduate program (2024) and is currently pursuing a master' s degree (2024–present) at the Graduate School of Pasundan University.
	Prof. Dr. Hj. R. Poppy Yaniawati, M.Pd. Born in Bandung on January 21, 1968, she is a lecturer at Pasundan University in Bandung who graduated with honors from the Master' s (2002) and Doctoral (2006) programs in Mathematics Education at the Indonesia University of Education. In 2014, he was appointed Professor (directly to the rank of Full Professor/IVe). She is the creator of NFT Sains, a blockchain-based marketplace for researchers, lecturers, and other education stakeholders, and received a matching grant from the University of Science Malaysia (USM) for the period 2021–2023.