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Development of 'EduGame Mathematics' Gamification-Based Application to Enhance Learning Interest of Elementary School Students in 3T Regions

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ABSTRACT

Background: The digital divide in Indonesia's underdeveloped, frontier, and outermost (3T) regions creates significant challenges for mathematics education in elementary schools. Traditional teaching methods often fail to engage students, resulting in low learning motivation and poor academic outcomes. Objective: This study aims to develop and evaluate the effectiveness of 'EduGame Mathematics,' a gamification-based mobile learning application designed to enhance learning interest among elementary school students in 3T regions. Methods: A quantitative experimental research design was employed using a pretest-posttest control group design. The study involved 120 elementary school students (grades 4-6) from three schools in 3T regions, randomly assigned to experimental (n=60) and control (n=60) groups. Data collection instruments included learning motivation questionnaires, mathematics achievement tests, and application usability assessments. Statistical analysis was conducted using independent t-tests and paired t-tests with SPSS 25.0. Results: The experimental group demonstrated significantly higher learning motivation scores compared to the control group (M=85.4, SD=8.2 vs M=68.7, SD=9.1; $t(118)=10.45$, $p<0.001$). Mathematics achievement scores showed substantial improvement in the experimental group, with a mean increase of 24.3 points (from 62.1 to 86.4), while the control group showed minimal improvement of 5.2 points (from 61.8 to 67.0). The application received high usability ratings (M=4.31/5.0) and demonstrated strong acceptance among students and teachers. Conclusion: The EduGame Mathematics application effectively enhances learning interest and achievement among elementary school students in 3T regions. The gamification approach successfully addresses educational challenges in resource-constrained environments, providing a scalable solution for improving mathematics education quality in remote areas of Indonesia.

Keywords: gamification, mobile learning, mathematics education.

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INTRODUCTION

Indonesia's commitment to achieving Sustainable Development Goal 4 (SDG 4) on quality education faces significant challenges, particularly in underdeveloped, frontier, and outermost (3T) regions. These areas, characterized by limited infrastructure, inadequate technological resources, and geographical isolation, struggle to provide equitable educational opportunities for their students. The digital divide exacerbates these challenges, creating substantial barriers to effective teaching and learning processes (Revaldhi et al., 2025).

Mathematics education in elementary schools presents particular difficulties across Indonesia, with students often experiencing low motivation and poor academic performance. Traditional pedagogical approaches frequently fail to engage young learners, especially in subjects perceived as abstract and challenging. This problem is amplified in 3T regions where educational resources are scarce and teacher training opportunities are limited (Ena Juliatni et al., 2025).

The integration of technology in education has emerged as a promising solution to address these challenges. Mobile learning applications, in particular, offer unique advantages in resource-constrained environments due to their accessibility, portability, and ability to function with minimal infrastructure requirements. Research demonstrates that well-designed educational technology can significantly improve learning outcomes, even in developing country contexts (Wardhana et al., 2025).

Gamification, defined as the application of game design elements and principles in non-educational contexts, has gained recognition as an effective pedagogical strategy for enhancing student engagement and motivation. Studies indicate that gamification can stimulate student interest, enhance motivation, and improve learning outcomes in mathematics education. The approach is particularly relevant for elementary school students who naturally gravitate toward play-based learning experiences (Yan, 2023).

Despite growing evidence supporting the effectiveness of gamification in mathematics education, limited research has focused specifically on its application in Indonesia's 3T regions. These areas face unique challenges including inconsistent internet connectivity, limited device availability, and varying levels of digital literacy among both students and teachers. Therefore, there is a critical need for educational technology solutions specifically designed to address these contextual constraints while maintaining pedagogical effectiveness (Liu, 2023).

This study addresses this gap by developing and evaluating 'EduGame Mathematics,' a gamification-based mobile learning application specifically designed for elementary school mathematics education in 3T regions. The application incorporates offline functionality, culturally relevant content, and intuitive user interfaces to overcome common technological barriers. The research aims to contribute to the growing body of knowledge on educational technology in developing countries while providing practical solutions for improving mathematics education quality in Indonesia's most underserved areas.

METHOD

This study employed a quantitative experimental research design using a pretest-posttest control group design to evaluate the effectiveness of the EduGame Mathematics application. This design allows for rigorous comparison between experimental and control conditions while controlling for potential confounding variables. The experimental group received instruction using the gamified mobile application, while the control group received traditional mathematics instruction without technological intervention.

The research design followed established principles of educational research, incorporating random assignment of participants to groups, standardized assessment instruments, and appropriate statistical analysis procedures. This approach enables causal inferences about the relationship between the gamification intervention and student learning outcomes.

The study involved 120 elementary school students from grades 4-6 (ages 9-12) across three schools in designated 3T regions of Indonesia. Schools were selected based on their 3T classification, willingness to participate, and availability of basic technological infrastructure necessary for the study. Students were randomly assigned to experimental (n=60) and control (n=60) groups using a computerized randomization procedure to ensure equal distribution across relevant demographic characteristics.

Inclusion criteria required students to be enrolled in grades 4-6, have basic literacy skills in Bahasa Indonesia, and have parental consent for participation. Exclusion criteria included students with severe learning disabilities or those who had previously used similar educational applications. The sample size was determined through power analysis, ensuring adequate statistical power to detect meaningful differences between groups.

The EduGame Mathematics application was developed using an iterative design process incorporating user-centered design principles and educational technology best practices. The development process followed the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework, which is widely recognized for educational technology development.

Analysis Phase: Comprehensive needs assessment was conducted through surveys, interviews, and focus groups with students, teachers, and educational administrators in 3T regions. This phase identified specific learning challenges, technological constraints, and user requirements that informed the application design.

Design Phase: The application architecture was designed to incorporate key gamification elements including points systems, achievement badges, progress tracking, interactive challenges, and immediate feedback mechanisms. Content was aligned with Indonesia's national mathematics curriculum for grades 4-6, covering topics such as basic arithmetic, geometry, fractions, and problem-solving.

Development Phase: The application was built using cross-platform development tools to ensure compatibility across various mobile devices. Offline functionality was prioritized to address connectivity limitations in 3T regions. User interface design emphasized simplicity, visual appeal, and intuitive navigation appropriate for elementary school students.

Implementation Phase: Pilot testing was conducted with small groups of students and teachers to identify usability issues and gather feedback for refinement. The application was iteratively improved based on user feedback before full-scale implementation.

Three primary instruments were used for data collection:

1. Learning Motivation Questionnaire: A validated 20-item instrument measuring student motivation toward mathematics learning was adapted from Keller's ARCS (Attention, Relevance, Confidence, Satisfaction) model. Items were rated on a 5-point Likert scale, with higher scores indicating greater motivation. The instrument demonstrated strong internal consistency (Cronbach's $\alpha = 0.89$) in pilot testing.

2. Mathematics Achievement Test: A comprehensive assessment covering grade-appropriate mathematics concepts was developed by expert mathematics educators. The test included 30 multiple-choice and 10 short-answer questions designed to measure conceptual understanding, procedural fluency, and problem-solving skills. Content validity was established through expert review, and test-retest reliability was confirmed ($r = 0.86$).

3. Application Usability Assessment: The System Usability Scale (SUS) was adapted for elementary school students to evaluate the EduGame Mathematics application. The instrument included items assessing ease of use, navigation clarity, visual appeal, and overall satisfaction with the application experience.

Data collection occurred over a 12-week period following a structured protocol:

Week 1: Pretest administration including motivation questionnaire and mathematics achievement test for both groups.

Weeks 2-11: Implementation of the intervention. The experimental group used the EduGame Mathematics application for 30 minutes daily during regular mathematics instruction periods. The control group received traditional mathematics instruction covering the same curriculum content. Both groups maintained regular classroom schedules and teacher-led instruction.

Week 12: Posttest administration using identical instruments to the pretest. Additionally, the experimental group completed the application usability assessment.

Statistical analysis was conducted using SPSS 25.0 software following established protocols for educational research. Descriptive statistics were calculated for all variables, including measures of central tendency, variability, and distribution characteristics. Independent samples t-tests were used to compare posttest scores between experimental and control groups. Paired samples t-tests analyzed within-group changes from pretest to posttest. Effect sizes were calculated using Cohen's d to determine practical significance of observed differences.

Prior to conducting primary analyses, data were examined for assumptions of normality, homogeneity of variance, and independence. Appropriate statistical procedures were implemented to address any violations of these assumptions. An alpha level of 0.05 was established for all statistical tests, with Bonferroni corrections applied for multiple comparisons where appropriate..

RESULTS AND DISCUSSION

The final sample consisted of 118 students (58 experimental, 60 control) after accounting for two dropouts due to school transfers. Demographic characteristics were well-balanced between groups. The experimental group included 31 females (53.4%) and 27 males (46.6%), while the control group included 32 females (53.3%) and 28 males (46.7%). Mean age was 10.2 years (SD=1.1) for the experimental group and 10.3 years (SD=1.2) for the control group, with no significant difference between groups (t(116)=0.47, p=0.641) (Mengyao et al., 2024).

Table 1. Participant Demographics and Characteristics

Characteristic	Experimental Group (n=58)	Control Group (n=60)	Total (N=118)
Gender			
Female	31 (53.4%)	32 (53.3%)	63 (53.4%)
Male	27 (46.6%)	28 (46.7%)	55 (46.6%)
Age			
Mean (SD)	10.2 (1.1)	10.3 (1.2)	10.25 (1.15)
Range	9-12 years	9-12 years	9-12 years
Grade Level			
Grade 4	19 (32.8%)	21 (35.0%)	40 (33.9%)
Grade 5	20 (34.5%)	19 (31.7%)	39 (33.1%)
Grade 6	19 (32.8%)	20 (33.3%)	39 (33.1%)
School Distribution			
School A	20 (34.5%)	21 (35.0%)	41 (34.7%)
School B	19 (32.8%)	20 (33.3%)	39 (33.1%)
School C	19 (32.8%)	19 (31.7%)	38 (32.2%)
Location Type			
Urban Area	24 (41.4%)	26 (43.3%)	50 (42.4%)
Rural Area	34 (58.6%)	34 (56.7%)	68 (57.6%)

Characteristic	Experimental Group (n=58)	Control Group (n=60)	Total (N=118)
Previous Technology Use	12 (20.7%)	14 (23.3%)	26 (22.0%)

Learning Motivation Outcomes

Analysis of learning motivation scores revealed significant differences between groups at posttest. The experimental group demonstrated substantially higher motivation scores (M=85.4, SD=8.2) compared to the control group (M=68.7, SD=9.1). An independent samples t-test confirmed this difference was statistically significant ($t(116)=10.45$, $p<0.001$, Cohen's $d=1.93$), indicating a large effect size (Mutmainnah et al., 2024).

Table 2. Pre-test and Post-test Learning Motivation Scores

Group	Pre-test M (SD)	Post-test M (SD)	Mean Change	95% CI of Change	t	p	Cohen's d
Experimental	69.1 (8.9)	85.4 (8.2)	+16.3	[13.8, 18.8]	12.81	<0.001	1.93
Control	68.9 (9.3)	68.7 (9.1)	-0.2	[-2.1, 1.7]	0.15	0.884	0.02

Within-group analyses showed significant improvement in motivation for the experimental group from pretest (M=69.1, SD=8.9) to posttest (M=85.4, SD=8.2), $t(57)=12.81$, $p<0.001$. The control group showed minimal change from pretest (M=68.9, SD=9.3) to posttest (M=68.7, SD=9.1), $t(59)=0.15$, $p=0.884$.

Examination of ARCS model components revealed that the experimental group showed particularly strong gains in the Attention (M=22.1 vs 17.3) and Satisfaction (M=21.8 vs 16.9) subscales, while Confidence (M=20.7 vs 17.2) and Relevance (M=20.8 vs 17.3) subscales also demonstrated significant improvements.

Mathematics Achievement Results

Mathematics achievement outcomes showed substantial differences favoring the experimental group. Posttest achievement scores were significantly higher for the experimental group (M=86.4, SD=7.8) compared to the control group (M=67.0, SD=8.9), $t(116)=12.75$, $p<0.001$, Cohen's $d=2.36$ (Meylani, 2025).

Table 3. Mathematics Achievement Test Results

Assessment	Experimental Group M (SD)	Control Group M (SD)	Mean Difference	95% CI of Difference	t	p	Cohen's d
Pre-test	62.1 (9.1)	61.8 (8.7)	0.3	[-2.8, 3.4]	0.19	0.851	0.03
Post-test	86.4 (7.8)	67.0 (8.9)	19.4	[16.2, 22.6]	12.75	<0.001	2.36

Assessment	Experimental Group M (SD)	Control Group M (SD)	Mean Difference	95% CI of Difference	t	p	Cohen's d
Change Score	+24.3 (8.5)	+5.2 (9.2)	19.1	[15.8, 22.4]	11.94	<0.001	2.18

The experimental group demonstrated a mean improvement of 24.3 points from pretest (M=62.1, SD=9.1) to posttest (M=86.4, SD=7.8), representing a paired t-test result of $t(57)=16.94$, $p<0.001$. In contrast, the control group showed minimal improvement of 5.2 points from pretest (M=61.8, SD=8.7) to posttest (M=67.0, SD=8.9), $t(59)=3.42$, $p=0.001$.

Analysis by mathematical content areas revealed that the experimental group showed particularly strong gains in problem-solving (39% improvement), geometry concepts (34% improvement), and fraction operations (31% improvement). These areas align well with the gamification elements that emphasized visual representations, interactive challenges, and step-by-step problem-solving guidance.

Application Usability and Acceptance

The EduGame Mathematics application received highly positive usability ratings from experimental group participants. Overall usability scores averaged 4.31 out of 5.0 (SD=0.42), indicating strong user satisfaction. Specific usability components showed particularly high ratings for ease of navigation (M=4.45, SD=0.39), visual appeal (M=4.38, SD=0.44), and engagement level (M=4.41, SD=0.41) (Widjayatri et al., 2022).

Qualitative feedback from students highlighted several appreciated features including the colorful and animated user interface, immediate feedback mechanisms, achievement badge systems, and the ability to track progress through different mathematical topics. Students particularly valued the application's offline functionality, which allowed continued learning despite intermittent internet connectivity common in 3T regions (Subramaniam et al., 2025).

Teacher feedback indicated high levels of acceptance and perceived usefulness of the application. Teachers reported that students demonstrated increased enthusiasm for mathematics lessons and greater willingness to engage with challenging mathematical concepts. Several teachers noted improved classroom participation and reduced mathematics anxiety among students using the application.

Table 4. Analysis of ARCS Motivation Model Components

ARCS Component	**Experimental Group**		**Control Group**		**Between-Group Effect Size**
	Pre-test M (SD)	Post-test M (SD)	Pre-test M (SD)	Post-test M (SD)	
Attention	17.2 (2.1)	22.1 (1.9)	17.4 (2.2)	17.3 (2.1)	2.31
Relevance	17.3 (2.3)	20.8 (2.1)	17.2 (2.4)	17.3 (2.3)	1.62

ARCS Component	Experimental Group		Control Group		Between-Group Effect Size
Confidence	17.1 (2.2)	20.7 (2.0)	17.0 (2.1)	17.2 (2.2)	1.73
Satisfaction	17.5 (2.0)	21.8 (1.8)	17.3 (2.2)	16.9 (2.1)	2.48

Addressing Educational Challenges in 3T Regions

The study results demonstrate that well-designed gamification interventions can effectively address several key educational challenges prevalent in Indonesia's 3T regions. The application's offline functionality successfully overcame connectivity limitations, while the intuitive user interface accommodated varying levels of digital literacy among students and teachers.

The significant improvements in both motivation and achievement suggest that gamification approaches can help compensate for resource limitations and teacher training gaps common in 3T regions. By providing structured, engaging learning experiences with immediate feedback, the application served as a valuable supplement to traditional instruction methods.

The study's findings align with broader research on mobile learning in developing countries, confirming that carefully designed educational technology can produce meaningful learning gains even in resource-constrained environments. The large effect sizes observed in both motivation and achievement outcomes suggest that gamification interventions may be particularly powerful in contexts where traditional educational approaches face significant limitations.

Table 5. Mathematics Achievement by Content Area

Content Area	Experimental Group		Control Group		Improvement Comparison
	Pre-test (%)	Post-test (%)	Pre-test (%)	Post-test (%)	(Exp vs Control)
Basic Arithmetic	58.3	89.7	57.8	62.4	+31.4% vs +4.6%
Geometry	52.7	87.3	53.1	58.7	+34.6% vs +5.6%
Fractions	48.9	84.2	49.2	54.8	+35.3% vs +5.6%
Problem Solving	46.2	88.1	45.9	52.3	+41.9% vs +6.4%
Measurement	55.1	86.4	54.8	59.1	+31.3% vs +4.3%
Data Analysis	51.8	83.9	52.2	56.7	+32.1% vs +4.5%

Table 6. EduGame Mathematics Application Usability Assessment Results

Usability Aspect	M	SD	Percentage Positive Rating (4-5)
Overall Satisfaction	4.31	0.42	92.3%
Ease of Use	4.28	0.45	89.7%
Navigation Clarity	4.45	0.39	96.5%
Visual Appeal	4.38	0.44	94.8%
Engagement Level	4.41	0.41	95.2%
Learning Effectiveness	4.33	0.38	91.4%
Offline Functionality	4.52	0.35	98.3%
Content Appropriateness	4.29	0.43	90.5%

Implications for Educational Technology in Developing Countries

These results contribute to the growing evidence base supporting educational technology implementations in developing country contexts. The study demonstrates that gamification approaches can be successfully adapted to address specific contextual challenges while maintaining pedagogical effectiveness.

The findings suggest several important considerations for future educational technology development in similar contexts. First, offline functionality is crucial for ensuring consistent access in areas with unreliable connectivity. Second, culturally relevant content and age-appropriate design elements are essential for maximizing user engagement. Third, comprehensive teacher training and support are necessary to ensure effective integration of technology into existing instructional practices.

The study also highlights the potential for scalable solutions to address educational inequities in remote and underserved areas. Given the widespread availability of mobile devices, even in remote regions, gamified learning applications could serve as cost-effective interventions for improving educational outcomes across Indonesia's 3T regions and similar contexts globally.

CONCLUSION

This study successfully demonstrates the effectiveness of the EduGame Mathematics application in enhancing learning interest and achievement among elementary school students in Indonesia's 3T regions. The gamification-based intervention produced significant improvements in both student motivation and mathematics achievement, with large effect sizes indicating substantial practical significance. The research findings provide strong evidence that well-designed educational technology can overcome traditional barriers to quality education in

resource-constrained environments. The application's offline functionality, culturally relevant content, and intuitive user interface successfully addressed key challenges specific to 3T regions, including limited connectivity, varying technological literacy levels, and resource constraints.

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