Designing and integrating mobile Damath: A digital game-based instructional innovation to enhance students' mathematical performance and engagement in integer operations

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Abstract: *This study examined the effectiveness of a mobile Damath game as a digital instructional design tool to enhance Grade 8 students' performance and engagement in integer operations. Conducted at Badas National High School, City of Mati, Davao Oriental, Philippines, the research utilized a quasi-experimental design involving 60 students equally assigned to experimental and control groups. The experimental group learned through the mobile Damath game, while the control group received traditional instruction. Data gathered using a validated mathematics achievement test and an AI-assisted engagement survey were analyzed using mean, standard deviation, t-test, and Pearson correlation. Results showed that both groups started at the Beginning proficiency level; however, the experimental group achieved a statistically significant improvement ($p = 0.004$) and advanced to the Developing level. Although engagement levels were high, no significant correlation was found between engagement and performance. The findings highlight the potential of digital game-based learning as an innovative instructional design approach that supports active, contextualized, and technology-driven learning. A strategic action plan was formulated to institutionalize mobile Damath integration in mathematics instruction, aligned with the BEDP 2030 and MATATAG Agenda for inclusive and future-ready education.*

Keywords: Game-based learning, Integer operations, Mobile Damath, Strategic plan, Student engagement.

1. Introduction

The persistent low performance of Filipino students in Mathematics, particularly in integer operations, remains a pressing educational concern (Mbarute & Ntivuguruzwa, 2022). Mastery of integers is not only a basic competency but also a preprequisite for later topics such as inequalities, algebraic equations, and problem-solving (Chong et al., 2022). Yet many learners struggle because they carry misconceptions about positive and negative numbers, which can weaken both conceptual understanding and accuracy in computation (Tanghal, 2020). This

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foundational difficulty is reflected in large-scale assessment results: the 2022 Programme for International Student Assessment (PISA) reported that only 16% of Filipino learners achieved Level 2 proficiency in Mathematics compared to the OECD average of 69%, and TIMSS 2019 reported an average score of 297, far below the international mean of 500 (Mullis et al., 2020; OECD, 2023). These outcomes point to the need for instruction that is not only evidenced-based but also responsive to how today's learners engage with content in digital learning environments.

In the context of Instructional Design in the Digital Era, mathematics teaching increasingly emphasizes active learning, meaningful interaction, and tools that help students construct understanding rather than memorize procedures. Game-based learning, particularly in digital formats, has gained attention because it can combine practice with motivation, feedback and sustained engagement. These conditions are often difficult to maintain in purely lecture-based instruction (Godoy, 2020; Cano et al., 2024). Studies in this area commonly report improved participation, interest, and enjoyment when learning activities resemble the interactive and learner-centered experiences students are familiar with (Shah, 2023; Sangode et al., 2024). In mathematics, these benefits are especially relevant because engagement can influence time-on-task, persistence, and willingness to work through challenging concepts.

One technology-enhanced approach that responds to these needs is the mobile Damath game**,** a digital adaptation of the traditional Filipino board game created by Jesus Huenda. By blending mathematical computation with strategic gameplay, mobile Damath aims to make integer operation more concrete and meaningful while increasing learners' motivation (Ramos et al., 2013; Baog, et al., 2024). Recent work describes mobile Damath and similar tools as contextually relevant interventions that can support active participation and create a more engaging learning climate (Ramirez & Mercado, 2023; Berdiyorovna & Uktamovna, 2025). However, the literature also suggests that the effect of game-based tools is not always uniform across outcomes: some studies highlight strong gains in engagement without significant improvements in performance, while others report advantages in cognitive and metacognitive processes that can translate to achievement over time (Baog et al., 2024; Shah, 2023; Sangode et al., 2024). This mixed evidence suggests that the value of mobile game-based interventions may depend on how engagement relates to measurable learning gains and how the intervention compares with traditional instruction in a specific context.

This concern is evident in Badas National High School, where Grade 8 learners have shown consistently low-test scores in integer operations and limited participation during Mathematics classes. Traditional approaches may not sufficiently address diverse learning needs or sustain interest, which can lead to weak retention and limited mastery of foundational skills (Chong et al., 2022; Tanghal, 2020). Given these realities, mobile Damath offers a student-centered and culturally grounded alternative that may help learners experience integer operations through meaningful interaction and healthy competition, potentially improving

both motivation and achievement (Ramirez & Mercado, 2023; Berdiyorovna & Uktamovna, 2025).

In response, this study investigates the effectiveness of the interactive mobile Damath game in improving Grade 8 students' performance in integer operations at Badas National High School. Specifically, it examined: 1) the relationship between students' engagement, measured through attitude and motivation, and their academic performance, and 2) the difference in outcomes between students exposed to mobile Damath and those taught through traditional instruction. Using quasi-experimental design with control and experimental groups, the study employed pre- and post-tests, and validated engagement surveys. Findings are expected to inform teachers' instructional decisions, support administrators and curriculum developers in adopting technology-based interventions, and guide parents and policymakers in strengthening digital approaches to mathematics learning. Ultimately, the study aligns with the Department of Education's K–12 reform goals of improving mathematics instruction and supporting learners' digital readiness.

This study adopted a unified conceptual framework explaining how mobile Damath may influence Grade 8 learners' integer-operation achievement by integrating technology acceptance, constructivist learning, and game-based learning (GBL). Drawn from Technology Acceptance Model (TAM), students are expected to engage more meaningfully when they perceive mobile Damath as useful and easy to use, fostering positive attitudes and willingness to participate (Davis, 1989; Venkatesh & Davis, 2000). Grounded by constructivist theory, learning is strengthened through active practice, timely feedback and reflection, which are embedded in the gameplay and reflection sessions (Vygotsky, 1978; Hattie & Timperley, 2007). Consistent with game-based learning research, the games' goals, rules, challenge, and feedback loops are expected to sustain motivation and time-on task, supporting skill development (Garris et al., 2017; Plass et al., 2015). Evidence from meta-analyses also indicates that game-based learning can enhance learning and motivation, including mathematics (Wouter et al., 2013; Tokac et al., 2019). Accordingly, the framework posits that mobile Damath influences post-test/gain scores partly through engagement (attitude and motivation), consistent with evidence linking engagement and achievement (Lei et al., 2018) and models of engagement in technology-mediated learning (Hu & Hui, 2012).

2. Methods

This study used a quasi-experimental design with pre- and post-tests involving experimental and control groups to examine the effect of Mobile Damath on students' performance in integer operations and their engagement. The experimental group played Mobile Damath as an instructional tool, while the control group received traditional teaching. Pre-tests established baseline performance, and post-tests measured learning gains.

Purposive sampling was employed in this study using intact Grade 8 classes from Badas National High School, Mati City, Davao Oriental, Philippines. All 106 Grade 8 learners took a pre-test on integer operations, and the 60 lowest-performing students were selected to examine the effect of mobile Damath among learners most in need of remediation. Eligible participants were enrolled in Grade 8 Mathematics, regularly attending, and had parental consent and willingness to participate; students with irregular attendance, no consent, or requiring specialized instruction were excluded. Because random assignment was impractical, intact classes were maintained to avoid disrupting school schedules (Creswell & Creswell, 2017), and the sample was divided into experimental (n = 30) and control (n = 30) groups with baseline comparability supported by pre-test results and pre-post measures.

Data were collected using a demographic questionnaire, a teacher-made 40-item pre- and post-test**,** and an AI-assisted engagement survey assessing motivation and attitude toward Mobile Damath. The pre- and post-test showed good reliability (Cronbach's $\alpha = 0.735$), while the engagement survey achieved strong reliability (Cronbach's $\alpha = 0.828$). Student performance was categorized according to DepEd standards, and engagement was rated on a five-point scale.

The intervention lasted three weeks with daily 60-minute sessions. Experimental group sessions included a 10-minute review, 40 minutes of gameplay, and a 10-minute reflection, while the control group received traditional instruction using lectures and exercises. Laptops and internet access were provided to ensure equitable use of Mobile Damath, and monitoring prevented misuse or cross-group contamination.

Data analysis involved descriptive statistics (mean, SD, frequency, percentage) and inferential tests (independent t-test for performance differences and Pearson correlation for engagement–performance relationships). Normality and homogeneity assumptions were verified to justify parametric testing.

Ethical considerations included approval from the university ethics board, informed consent from participants and parents, voluntary participation, data confidentiality, and mitigation of risks such as screen fatigue. The control group received access to Mobile Damath after the study to ensure fairness.

3. Results

3.1 Demographic profile of respondents

The demographic characteristics of the respondents provide context for interpreting results (Table 1). Most respondents (48.33%) were 14 years old, corresponding to the typical age range for Grade 8 students. In terms of g ender, 60% were male and 40% were female, indicating a slightly male-dominated sample.

Table 1. Demographic profiles of the participants

Groups	Frequency (n=60)	Percentage (100%)
Age		
13 years old	10 (Exp), 10 (Ctrl)	20
14 years old	13, 16	29
15 years old	4, 3	7
16 years old	3, 1	4
Gender		
Male	16, 20	36
Female	14, 10	24

3.2 Pre-test performance of students

Prior to intervention, a pre-test on integer operations established the baseline proficiency of both groups. Results revealed that the majority scored between 10 and 15 out of 40 items, suggesting limited mastery (see Figure 1). The experimental group (see Figure 2) had a mean score of 11.43 (SD = 4.58), while the control group scored 11.23 (SD = 4.07) (see Figure 3), both falling under the Beginning proficiency level (≤74%). The nearly identical averages confirm the initial comparability of the two groups.

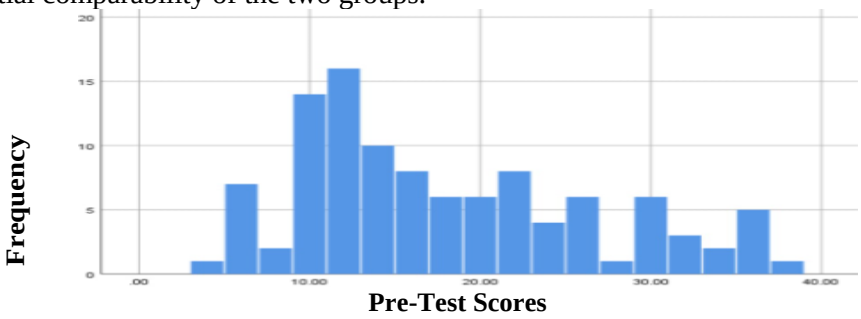

Figure 1. Pre-test score distribution: grade 8 integer operations

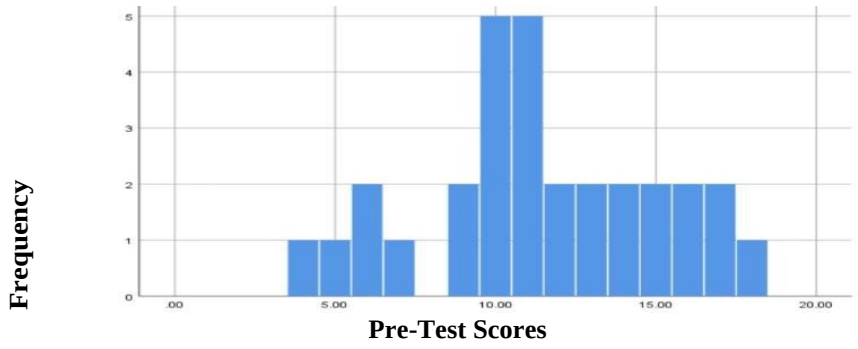

Figure 2. Pre-test performance of grade 8 students in the experimental group

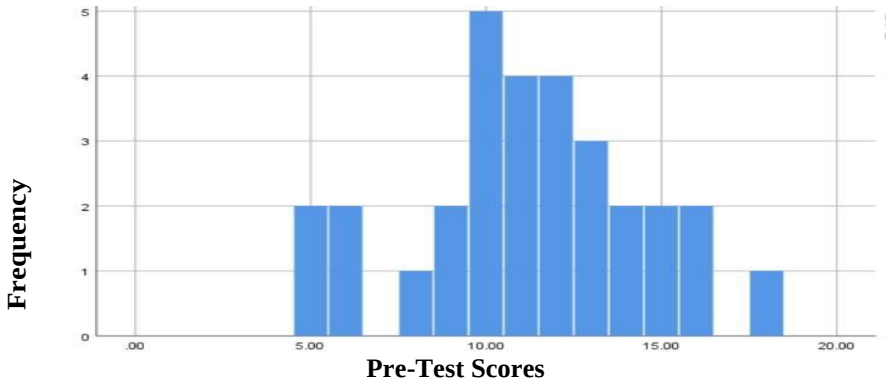

Figure 3. Visual representation of the pre-test results of the control group

3.3 Students' engagement with the Mobile Damath game

Students' engagement with the Damath game was evaluated in terms of attitude and motivation. Results indicated very high engagement levels across both dimensions (see Table 2). In terms of attitude, mean scores ranged from 4.37 to 4.60, with an overall mean of 4.48 (SD = 0.28). For motivation, scores ranged from 4.03 to 4.77, with an overall mean of 4.47 (SD = 0.28). Students reported strong enjoyment, attentiveness, and perseverance during gameplay.

Table 2. Student Engagement Mobile Damath: attitude and motivation

	Mean	SD	Descriptive Interpretation
Attitude			
I regularly engage in the mobile Damath game as part of my daily routine	4.47	0.57	Very High
I actively participate in the gameplay with others on a regular basis.	4.37	0.61	Very High
I prefer to play the game alone with an AI opponent	4.53	0.63	Very High
I am highly focused and attentive while playing the mobile Damath game	4.43	0.50	Very High
I enjoy competing and strategizing while playing the mobile Damath game.	4.47	0.51	Very High
I keep track of my previous scores/record to monitor my progress	4.60	0.50	Very High
Overall	4.48	0.28	Very High
Motivation			
I play the mobile Damath game regularly to challenge myself and test my abilities.	4.03	0.49	High

I am motivated to play the mobile Damath game because it is enjoyable and fun.	4.43	0.50	Very High
I enjoy playing the mobile Damath game because it allows me to compete with others.	4.23	0.57	Very High
I am motivated to learn new strategies to improve my performance in the mobile Damath game.	4.30	0.65	Very High
I enjoy the challenge of solving difficult problems in the mobile Damath game.	4.37	0.67	Very High
I feel overwhelmed every time I get high score over my opponent	4.53	0.51	Very High
My progress in the mobile Damath game motivate me to play more	4.40	0.50	Very High
I feel a sense of accomplishment when I complete a level in the game	4.47	0.51	Very High
I am driven to understand the rules of the mobile Damath game deeply to improve my skills	4.77	0.43	Very High
Overall	4.47	0.28	Very High

3.4 Post-test performance and comparative analysis

After three weeks of implementation, both groups took a post-test to assess improvement. The experimental group achieved a mean score of 77.35% (SD = 4.23), corresponding to the Developing level, while the control group scored 73.61% (SD = 5.44), remaining within the Beginning level (see Table 3).

Table 3. Post-test mathematics performance: experimental vs control

	Groups	Average	Proficiency Level	SD	df	t-stat	P-value	Decision on H_o
Post-Test	Experimental (n=30)	77.35 %	Developing Level	4.23	58	2.972	0.004	Reject
	Control (n=30)	73.61 %	Beginning Level	5.44				

An independent samples t-test revealed a statistically significant difference between the groups, $t(58) = 2.972$, $p = 0.004$, with an effect size (Cohen's $d = 0.77$) indicating a moderate to large impact. The experimental group's improvement from 64.29% to 77.35% demonstrates that the Damath intervention effectively enhanced comprehension and performance in integer operations.

3.5 Relationship between engagement and academic performance

Correlation analysis examined the link between engagement (attitude and motivation) and academic performance. The results showed a significant positive correlation between attitude and motivation ($r = 0.371$, $p = 0.044$), confirming that positive attitudes foster motivation (see Table 4). However, the correlations between engagement and math performance were negative and statistically insignificant (attitude, $r = -0.101$, $p = 0.594$; motivation, $r = -0.045$, $p = 0.814$).

Table 4. Performance-engagement correlation in damath (attitude and motivation)

Attitude			Motivation	Overall Student Engagement	Math Performance
Attitude	r-value	1	.371	.822	-.101
	p-value		.044	0.001	.594
Motivation	r-value		1	.833	-.045
	p-value			.000	.814
Overall Student Engagement	r-value			1	-.088
	p-value				.645
Math Performance	r-value				1
	p-value				

4. Discussion

The study demonstrates that Mobile Damath significantly enhanced students' mathematical performance compared with traditional instruction. The experimental group achieved a post-test mean of 77.35% (Developing level), while the control group remained at the Beginning level. The moderate-to-large effect size (Cohen's $d=0.77$) suggests that a well-designed digital game can meaningfully improve conceptual understanding in integer operations.

The results can be explained theoretically through a combined constructivist and game-based learning lens: mobile Damath situates integer practice in an interactive setting where learners actively test strategies, receive immediate feedback, and refine misconceptions, conditions central to knowledge construction (Plass et al., 2015). Consistent with TAM, the high motivation ($M = 4.77$) and attitude ($M = 4.60$) scores indicate that perceived usefulness and enjoyment can support students' willingness to engage with the tool (Davis, 1989; Sun et al., 2021). However, the lack of a direct engagement-performance correlation implies that motivation alone does not guarantee learning engagement: achievement gains are more likely when gameplay is paired with teacher-guided scaffolding and

reflection that helps students consolidate concepts and transfer learning to assessments (Hillmayr et al., 2020)

These findings align with previous studies showing that digital and game-based interventions improve learning outcomes by fostering active participation, immediate feedback, and contextualized experiences (Magsombol, 2021; Cano et al., 2024; Plass et al., 2015; Sharma & Shukla, 2023). High engagement and positive attitudes, reflected in motivation **(**M = 4.77**)** and attitude **(**M = 4.60**)** scores, support the Technology Acceptance Model (TAM), suggesting that perceived usefulness and enjoyment drive the adoption of educational technology (Davis, 1989; Sun et al., 2021). Students reported enjoyment, competitiveness, and focus, demonstrating that Mobile Damath can make mathematics interactive, appealing, and relevant for digital-native learners.

The absence of a direct correlation between engagement and performance highlights that motivation alone is insufficient to guarantee achievement, reinforcing the need for structured guidance, reflection, and scaffolding (Okigbo & Onoshakpokaiye, 2023; Sangode et al., 2024). Pedagogically, teacher-mediated debriefing ensures that students actively construct knowledge and consolidate conceptual understanding (Hillmayr et al., 2020).

Hence, these findings show that strategically designed digital games, integrated with scaffolding and feedback, exemplify learner-centered instructional design in the digital era**,** offering a sustainable, effective approach to enhance both engagement and learning outcomes in mathematics education.

5. Conclusion

The study demonstrates that Mobile Damath effectively enhances students' performance in integer operations**,** highlighting the value of interactive, game-based learning in the digital era**.** Significant gains in the experimental group indicate that well-designed digital interventions can meaningfully supplement traditional instruction. High engagement and positive attitudes reflect the motivational potential of mobile-based learning, while the need for structured guidance and reflective activities underscores the importance of instructional design in converting engagement into conceptual mastery. Aligning with constructivist principles and the Technology Acceptance Model**,** these findings suggest that Mobile Damath provides a scalable, technology-driven, learner-centered approach for enhancing engagement, achievement, and meaningful learning in 21st-century mathematics education.

The findings suggest that mobile Damath can effectively support learninf in integer operations, but its benefits are greatest when gameplay is teacher-guided rather than treated as stand-alone activity. Teachers should set clear learning targets, use short timed practice cycles, and include "stop-and-check" prompts that require students to justify their move, supported by simple tools such as a misconception checklist and brief reflection log. To address differences in game literacy, a short orientation and low-stake practice round should be provided, with

strategic pairing of roles (player, checker, explainer) to ensure equitable participation. Finally, teachers should manage cognitive load by chunking gameplay by concept, providing visual aids, and conducting a consistent debriefing after each session to connect game actions to formal integer rules and strengthen transfer to assessments.

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