

Next- Level Science Instruction: The Development of Digital Application on Students' Engagement and Students' Achievement in Earth Science

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ABSTRACT

Science education remains a significant challenge for many students due to its abstract concepts and complex theories, often resulting in low participation and poor academic performance. In the Philippines, international assessments such as PISA and TIMSS consistently report low achievement in science, indicating that students struggle to master key science competencies. This highlights a clear gap in effective and innovative instructional strategies that can improve learning outcomes, emphasizing the need for research-driven approaches in teacher education and the integration of technology in science instruction. This study aimed to address this gap by developing a digital application and evaluating its students' engagement and effectiveness in enhancing the academic performance of Grade 9 students. A quantitative quasi-experimental repeated-measures design was employed. Students utilized an offline digital application comprising instructional modules, interactive games, and video lessons. Students completed a survey to determine the effectiveness of the digital application in enhancing their engagement, while pretest and posttest assessments were administered to measure their academic performance before and after the intervention. Findings indicated that the digital application generated high levels of student engagement. Students' academic performance improved significantly from pretest to posttest. The study concludes that digital application-based instruction is an effective and innovative approach for enhancing science learning. These results have important implications for teacher education, curriculum development, and the integration of technology-driven instructional strategies in science classrooms, contributing to the preparation of scientifically literate and globally competent learners.

Keywords: *digital application, science education, student achievement, student engagement, and technology-enhanced learning*

Introduction

Students often have trouble in learning science due to its abstract concepts and complex theories. To address this concern, technology particularly digital game-based tools can be integrated into instruction to make scientific concepts more interactive, meaningful, and easier to understand. Moreover, digital game-based learning has been shown to support the development of 21st-century skills such as critical thinking, problem-solving, and conceptual understanding, which are essential in preparing students for future-ready learning environments (Wang et al., 2022). Studies support the integration of

digital tools in science education. In the United States, Reed et al. (2022) found that students' interest in science declines as they advance to higher grade levels due to increasing subject complexity and changes in instructional support systems. Similarly, studies in Indonesian junior high schools indicate that science instruction is still largely dominated by traditional teacher-centered methods, which result in passive learning and low student engagement (Agustiningrum et al., 2021; Mizwar et al., 2026). Science education plays a crucial role in developing learners' thinking and problem-solving skills, enabling them to apply scientific knowledge in real-life situations (De los Santos et al., 2025, p. 2).

However, despite its importance, students continue to struggle with abstract scientific concepts. This difficulty is reflected in international assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), where the Philippines consistently ranks among the lowest-performing countries in science (Acido & Caballes, 2024; Bernardo et al., 2023).

In the Philippine context, science remains a core subject under the K to 12 curriculums aimed at developing scientific literacy and higher-order thinking skills (Bibon, 2022, p. 2). However, studies show that students in some divisions, including Sultan Kudarat, continue to perform at low to fair levels in science. This persistent trend highlights the need for more effective and innovative instructional strategies to improve students' science achievement (Alair, 2020, p. 114; Macalikod, & Simpall, 2025, p. 196; Amaro et al., 2023, p. 122). Taken together, these findings reveal a need for more effective and innovative instructional approaches to improve science learning outcomes. Thus, there is a need to develop a digital application that enhances science instruction through more interactive and meaningful learning experiences. This study, therefore, aims to develop such an application and evaluate its effectiveness in improving students' engagement and academic performance in science.

Methods

Pedagogical Setting & Participants

The study was conducted at Bai Saripinang National High School, located in Barangay Bai Saripinang, Municipality of Bagumbayan, Sultan Kudarat, Philippines. The school is a public secondary institution with a total enrollment of 568 students, consisting of 275 females and 293 males, coming from several nearby barangays. Its diverse student population provided an appropriate setting for

examining the effects of different teaching approaches on students' academic achievement. The respondents of this study were thirty-three (33) Grade 9 Mahogany students of Bai Saripinang National High School, Barangay Bai Saripinang, Bagumbayan, Sultan Kudarat, Philippines, who were officially enrolled during the academic year 2025–2026.

Design of the Study

This study utilized a quantitative quasi-experimental repeated-measures design to determine the effectiveness of a digital application in improving students' science performance. The same participants were assessed before and after the intervention, allowing for direct measurement of change (Creswell & Creswell, 2018).

This design is appropriate where random assignment is not feasible and enables analysis of within-group changes while controlling individual differences. Its strength lies in detecting performance changes using the same participants. However, it is limited by the absence of a control group, which may introduce threats to internal validity such as testing effects and external influences. To address these limitations, the study maintained consistent procedures, controlled the duration of the intervention, and used the same assessment instrument for both pretest and posttest to ensure reliability (Fraenkel et al., 2019).

Data collection & analysis

Data were collected using two primary instruments: a survey questionnaire and a researcher-developed test questionnaire. A survey questionnaire was used to assess students' level of engagement in digital game-based instruction. The instrument consisted of 30 items designed to measure three dimensions of engagement: cognitive, behavioral, and motivational engagement, with 10 items assigned to each category. These

dimensions were selected to provide a holistic understanding of how students interact with and respond to the instructional approach. The respondents rated each statement using a four-point Likert scale: strongly agree, agree, disagree, and strongly disagree. The use of this instrument allowed the researcher to examine the extent to which the digital application facilitated active participation, sustained attention, and intrinsic motivation among learners.

To measure students' academic performance, a 60-item researcher-developed pretest and posttest were administered. These instruments were aligned with the targeted learning competencies to ensure content validity. Both the survey questionnaire and the pretest-posttest were validated by a panel of six experts, including three faculty members from Sultan Kudarat State University and three Department of Education Science Master Teachers. Their expertise ensured the clarity, relevance, and appropriateness of all test items and survey statements.

Participants were selected through purposive sampling. Thirty-three (33) Grade 9 students from the Mahogany section of Bai Saripinang National High School were included based on the criterion of having a science grade between 85 and 90. This selection ensured a relatively homogeneous group with sufficient prior knowledge, enabling a more accurate assessment of the intervention's

effectiveness, as participants with adequate baseline proficiency are more likely to engage meaningfully and produce valid assessment outcomes (Gay et al., 2012).

For data analysis, descriptive statistics, specifically mean and standard deviation, were used to summarize students' academic performance and assess student engagement with the digital application. A paired sample t-test was employed to determine whether there was a significant difference between pretest and posttest scores. The analysis was conducted at a 0.05 level of significance to establish whether the observed improvements were statistically significant. Overall, these methods ensured a systematic approach to data collection and analysis, strengthening the reliability, validity, and rigor of the study's findings.

Results

Level of Students' Engagement in Science Through Digital Application

This section presents the findings corresponding to the first specific objective, which aims to determine the level of students' engagement in terms of cognitive, behavioral, and motivational dimensions after exposure to the digital application. Student engagement is a key indicator of how learners actively interact with instructional materials, participate in learning activities, and sustain their interest and motivation throughout the learning process.

Table 1. Level of Students' Engagement in Science Through Digital Application

	Dimension	n*	M	SD
1	Cognitive Engagement	33	3.50	0.28
2	Behavioral Engagement	33	3.50	0.31
3	Motivational Engagement	33	3.54	0.31
	Overall mean		3.51	0.30

The results presented in Table 1 reveal that students demonstrated

consistently high engagement across cognitive, behavioral, and motivational dimensions when exposed to the digital application. As reflected in the summary table, Cognitive Engagement ($M = 3.50$, $SD = 0.28$) and Behavioral Engagement ($M = 3.50$, $SD = 0.31$) obtained identical mean scores, while Motivational Engagement obtained the highest mean ($M = 3.54$, $SD = 0.31$), with an overall mean of 3.51 ($SD = 0.30$), indicating high engagement among Grade 9 students. This suggests that digital game-based instruction effectively captures students' attention, promotes active participation, and sustains interest in learning science.

In terms of cognitive engagement, students demonstrated strong mental involvement through critical thinking, problem-solving, and concept connection while using the digital app. The high rating indicates that the instructional approach supports deeper understanding and meaningful learning, consistent with constructivist learning theory, where learners actively construct knowledge through interaction and experience. The results show that game-based tasks promote higher-order thinking and enhance conceptual understanding.

Regarding behavioral engagement, students actively participated in activities, showed persistence in completing tasks, and maintained focus during learning. The findings suggest that the digital app encourages observable learning behaviors such as task completion, exploration, and sustained effort. However, slightly lower variation in self-monitoring and strategic problem-solving indicates a need to further strengthen self-regulated learning through features such as progress tracking, reflective prompts, and guided strategies.

In terms of motivational engagement, students reported high enjoyment, interest, and willingness to participate in learning activities. The findings indicate that game-based elements

such as challenges, rewards, and interactivity enhance motivation and foster a positive attitude toward learning. However, slightly lower responses in confidence and anticipation suggest differences in self-efficacy, indicating the need for adaptive feedback, scaffolded difficulty, and recognition systems to further support motivation.

Taken together, the results demonstrate that digital application provides a balanced and holistic learning experience, addressing not only students' cognitive needs but also their behavioral involvement and motivational drive. The consistency of high engagement across all three dimensions indicates that the instructional approach is effective in creating an interactive, student-centered, and engaging learning environment.

From an educational perspective, these findings suggest that digital application is an effective pedagogical tool for enhancing science learning. By integrating interactive features, meaningful challenges, and immediate feedback, it transforms traditional instruction into a more engaging and immersive experience while supporting critical thinking, persistence, and intrinsic motivation.

Students generally show positive attitudes toward gamified learning when it is engaging, attainable, and aligned with learning objectives. This is supported by Aguilos and Fuchs (2022), Xiao (2025), and Thurairasu (2022), who emphasize that timely feedback and goal relevance enhance satisfaction and motivation. Al-Khayat et al. (2023) further support that game-based learning improves motivation, engagement, and cognitive skills by fostering interactive environments that promote problem-solving, critical thinking, and collaboration.

The effectiveness of digital game-based instruction in enhancing cognitive, behavioral, and motivational engagement is well supported in the literature (Barroso-

Tristan et al., 2025; Florese, 2025). It improves cognitive engagement through better processing and problem-solving, behavioral engagement through persistence and active participation, and motivational engagement through autonomy, competence, and relatedness. However, its impact depends on alignment with learning objectives, learner differences, and continuous refinement to prevent fatigue and sustain effectiveness (Stiver et al., 2025).

Level of Students' Academic Achievement in Science Through Digital Application

This section presents the findings on the level of students' academic achievement after exposure to the digital application. Academic achievement serves as a key measure of learning outcomes, reflecting the extent to which students have attained the intended instructional goals and mastered the required competencies.

Table 2. Level of Students' Academic Achievement in Science Before and After the Implementation of Digital Application

Module	Pretest Mean	SD	Posttest Mean	SD	Mean Difference	Interpretation
Module 1	6.58	2.17	8.88	1.11	-2.30	Improved
Module 2	5.88	2.09	8.42	1.28	-2.55	Improved
Module 3	6.48	2.54	9.00	0.90	-2.52	Improved
Module 4	6.79	2.43	9.30	0.81	-2.52	Improved
Module 5	6.88	2.70	9.33	1.05	-2.45	Improved
Module 6	5.91	2.57	9.64	0.65	-3.73	Improved
Overall	38.52	9.44	54.58	2.82	-16.06	Significantly Improved

The results presented in the table 2 show a clear improvement in students' academic achievement in science after the implementation of digital application instruction. The overall mean score increased from 38.52 in the pretest to 54.58 in the posttest, resulting in a mean difference of -16.06, which indicates a substantial gain in students' performance. This improvement suggests that the use of the digital application had a positive effect on students' learning outcomes. In addition, the decrease in standard deviation from 9.44 (pretest) to 2.82 (posttest) implies that students' scores became more consistent after the intervention, indicating a more uniform level of understanding among learners.

Across the six modules, all results consistently show improvement, as reflected by negative mean differences, which indicate that posttest scores were higher than pretest scores in all cases. Among the modules, Module 6 exhibited

the highest gain ($M = -3.73$), suggesting that students showed the greatest improvement in this area, possibly due to increased familiarity with the digital game-based environment or improved instructional design in the later stages of the intervention. In contrast, Module 1 showed the lowest gain ($M = -2.30$), which may be attributed to students' initial adjustment to the digital game-based learning approach. Despite these variations, all modules demonstrated meaningful improvements, indicating that the intervention was effective across different content areas.

Overall, the findings imply that the digital application is an effective instructional strategy for enhancing students' academic achievement in science. The consistent improvement across all modules highlights its potential to make learning more engaging, interactive, and accessible. These results support the integration of game-based instructional approaches in science education, as they not

only enhance academic performance but also promote a more consistent and equitable learning experience among students.

Digital applications enhance intrinsic motivation and perseverance by making learning engaging and purposeful, often leading to improved academic performance (Vlachopoulos & Makri, 2017). This supports the interpretation of the present study, which indicates that digital game-based instruction (DGBI) effectively strengthens cognitive engagement and academic achievement among secondary learners. Setiawati et al. (2024) likewise support this interpretation, showing that game-based learning increases students' motivation and participation by transforming lessons into interactive and challenging tasks, which ultimately improves learning outcomes.

Similarly, existing literature supports the interpretation that Digital Game-Based Learning (DGBL) enhances

engagement, motivation, and achievement when aligned with instructional objectives and proper implementation. Studies consistently show that it fosters student-centered and interactive learning environments that promote collaboration and critical thinking (Deng et al., 2024; Zeng et al., 2024). Although challenges such as teacher readiness and resource availability may affect implementation (Lampropoulos, 2023), the evidence still supports the interpretation that well-designed DGBL contributes significantly to improved student engagement and academic performance.

Significant Difference in Students' Academic Achievement

This section examines whether there is a significant difference in students' academic achievement after exposure to the digital application. This analysis is essential in determining if any observed changes in performance are statistically meaningful.

Table 3. Differences in Students' Academic Achievement Before and After the Implementation of Digital Application

Variable	M	SD	MD	t	df	p
Students' academic achievement before and after the implementation of digital application						
Pretest	38.52	9.44	-16.06	-10.69	32	.001
Posttest	54.58	2.82				
Paired Samples t-test						

The results presented in Table 3 show the outcomes of the paired samples t-test conducted to determine the difference in students' academic achievement before and after the implementation of the digital application. The findings reveal a statistically significant improvement in students' overall academic performance, as indicated by the mean difference of -16.06 and a highly significant t-value ($t(32) = -10.69, p < .001$). This indicates that the

increase in posttest scores is not due to chance, but is a result of the intervention. The negative mean difference further confirms that students performed better after the implementation of the digital application compared to their pre-intervention performance.

In addition, the results show a reduction in the variability of scores, as reflected in the lower standard deviation of

the posttest compared to the pretest. This suggests that students' performance became more consistent after the intervention, indicating that the digital application helped equalize learning outcomes among students. Such improvement in score consistency implies that more learners were able to achieve a similar level of understanding after exposure to the instructional tool.

Overall, the findings demonstrate a significant and meaningful improvement in students' academic achievement in science following the use of the digital application. The substantial increase in mean scores highlights the strong instructional impact of the intervention in enhancing conceptual understanding and academic performance. This suggests that the digital application effectively supports learning by making instructional content more engaging, structured, and accessible to students.

From an educational perspective, these results imply that the digital application is an effective instructional strategy for improving student achievement in science. The significant overall gain supports its potential integration into classroom instruction as an innovative teaching approach that enhances learning outcomes and promotes better academic performance.

In conclusion, the paired samples *t*-test results confirm that the digital application significantly improves students' academic achievement in science. These findings strongly support the integration of digital game-based instructional approaches as an effective and innovative method in science education. Orhan (2025) and Gui et al. (2023), through systematic reviews and meta-analyses, consistently demonstrated that Digital Game-Based Instruction (DGBI) produces positive effects on learners' knowledge, skills, and overall academic performance, with effect sizes

ranging from small to moderately large depending on the instructional context (Barz et al., 2023). The convergence of findings across diverse disciplines such as health professions, STEM, language learning, and general higher education further strengthens this interpretation, indicating that DGBI can lead to meaningful improvements compared to traditional instructional approaches, although outcomes may still vary across settings and implementations (Sailer & Homner, 2020). Taken together, these results support the interpretation that DGBI is an effective instructional approach when properly designed and implemented. Accordingly, integrating game-based strategies into instruction is justified, particularly in learning environments where engagement and motivation are limiting factors (Lie et al., 2024; Amzalag et al., 2024). However, the effectiveness of DGBI is strongly dependent on appropriate instructional design, teacher readiness, and the integration of suitable pedagogical strategies, as well as continuous refinement of implementation practices to ensure alignment between game mechanics and learning objectives (Carrion Candel et al., 2025).

Discussion

This study was conducted to determine the effectiveness of the developed digital application in enhancing students' engagement and academic achievement in science. The findings reveal that students demonstrated high engagement across cognitive ($M = 3.50$, $SD = 0.28$), behavioral ($M = 3.50$, $SD = 0.31$), and motivational dimensions ($M = 3.54$, $SD = 0.31$), with an overall mean of 3.51 ($SD = 0.30$), indicating strong engagement among Grade 9 learners. In addition, academic performance significantly improved after the intervention, as shown by the increase in mean scores from 38.52 (pretest) to 54.58 (posttest), with a significant difference ($t(32) = -10.69$, $p < .001$). These results

suggest that the digital application is effective in improving both engagement and learning outcomes in science.

The high engagement levels indicate that the digital application effectively promotes active participation, sustained attention, and motivation in learning. Cognitive engagement reflects improved critical thinking and conceptual understanding, consistent with constructivist learning theory, which emphasizes active knowledge construction. Behavioral engagement shows that students were actively involved and persistent in completing learning tasks, while motivational engagement indicates increased interest and enjoyment in learning, although slight variations in confidence suggest the need for further scaffolding and adaptive feedback.

The significant improvement in academic achievement confirms the effectiveness of the intervention. The consistent gains across all learning areas indicate that students benefited from the digital application regardless of content difficulty. The reduction in standard deviation from 9.44 to 2.82 further suggests more consistent student performance after the intervention, indicating more equalized learning outcomes.

The results of the paired samples t-test confirm that the improvement in scores is statistically significant, indicating that the observed gain is attributable to the use of the digital application rather than chance. These findings align with previous research on digital game-based learning, which highlights its positive effects on student engagement, motivation, and academic performance due to interactive, engaging, and feedback-rich learning environments. The study has both theoretical and practical implications. Theoretically, it supports constructivist and game-based learning theories, which emphasize active participation, interaction, and knowledge construction through technology-enhanced

environments. Practically, the findings suggest that the digital application can serve as an effective instructional resource that enhances student engagement, improves comprehension, and supports more interactive and learner-centered science teaching. Overall, the results confirm that the developed digital application is an effective and valid instructional approach that enhances both student engagement and academic achievement, supporting its integration into science classroom instruction.

Conclusion

The study concludes that the developed digital application is an effective instructional tool for enhancing science learning, as evidenced by its ability to promote strong learner engagement and improve academic performance. The high levels of cognitive, behavioral, and motivational engagement indicate that the application successfully fosters active learning, sustained participation, and increased interest in science. This suggests that the digital environment was able to create meaningful learning experiences that encourage students to interact more deeply with the subject matter and remain consistently involved in learning tasks.

In terms of academic performance, the findings confirm that students demonstrated substantial learning gains after the intervention, indicating that the use of the digital application positively influenced their understanding of science concepts. The improvement in performance consistency further suggests that the intervention helped minimize learning gaps among students, leading to more uniform achievement outcomes. Overall, the results demonstrate that the digital application is not only effective in improving academic achievement but also in supporting a more engaged and balanced learning experience among learners.

The study was conducted within a

limited scope, involving 33 Grade 9 students from a single school, which provides a focused context for examining the effectiveness of the intervention. The use of a quasi-experimental design also allowed for practical classroom-based implementation. These conditions supported the collection of relevant and meaningful data aligned with the objectives of the study.

Future research may consider expanding the sample size and including participants from multiple schools to improve the generalizability of the findings. The use of a control group is also recommended to strengthen the comparative evidence of the intervention's effectiveness. In addition, further studies may examine the application of the digital tool in other subject areas to determine its adaptability and effectiveness across different science topics and competencies, thereby further establishing its instructional value in varied learning contexts.

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Biodata

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