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Innovative Approach Using Augmented Reality Technology in Teaching Grade 10 Earth Science: Its Impact on Learners' Academic Performance

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Abstract: Augmented reality (AR) technology presents innovative opportunities to enhance science instruction by offering interactive visualizations of abstract geological concepts. This study developed an Android-based AR instructional application and examined its impact on the academic performance of Grade 10 learners in Earth Science at Kaunlaran High School, Schools Division of Navotas City, Philippines, during the first grading period of the school year 2021–2022. A quantitative pretest–posttest control-group design was employed involving 80 learners, with 40 participants in each group. The developed application comprised five instructional modules aligned with the Department of Education's Most Essential Learning Competencies. Academic performance was assessed using a 50-item teacher-made achievement test, while descriptive statistics and independent-samples t-tests were employed for data analysis at the 0.05 significance level. Pretest results indicated no statistically significant difference between the control (M = 16.20) and experimental (M = 16.83) groups (p = 0.639). However, posttest results demonstrated significantly higher academic performance among experimental-group learners (M = 26.15) compared with control-group learners (M = 22.00), p = 0.021. Descriptive mean gains were 9.32 and 5.80 points, respectively. These findings suggest that AR-assisted instruction may enhance learners' academic performance by supporting the visualization and understanding of complex Earth Science concepts. The developed application represents a promising supplementary instructional resource, although further investigations involving broader samples and extended interventions are recommended to establish its effectiveness across diverse educational contexts and learning environments.

Keywords: augmented reality, Earth Science education, academic performance, Grade 10 learners, technology-enhanced learning

INTRODUCTION

Science education plays a crucial role in nurturing scientific literacy, honing critical thinking, and sharpening problem-solving skills, while helping learners unravel the mysteries of natural phenomena. However, teaching Earth Science presents its own set of challenges. Concepts such as plate tectonics, earthquakes, volcanic activity, and geological processes are intricate puzzles, involving complex structures and movements that remain invisible within the confines of a classroom (Pallant et al., 2024; Wellmann et al., 2022). This is where augmented reality (AR) steps in as a gamechanger. By blending digital 3D representations with the tangible world, AR allows learners to visualize and interact with these abstract scientific concepts (Mansour et al., 2024; Zimmerman et al., 2023). Research has demonstrated that AR can significantly enhance academic performance, deepen conceptual understanding, and boost motivation and engagement in science education (Amores-Valencia et al., 2023; Ferrari et al., 2024; Kalemkuş & Kalemkuş, 2023).

In the Philippines, getting students to understand science is a major priority. The country's performance in international tests, such as the Programme for International Student Assessment (PISA), shows that there is still a lot of work to be done when it comes to scientific literacy. This highlights the need for new, student-centred teaching methods (OECD, 2023). In Grade 10 Science, the Department of Education covers topics such as the Earth's crust, plate boundaries, earthquake epicenters, volcanic activity, and tectonic movements. These subjects require spatial

reasoning and the ability to visualize concepts, which is why using technology in teaching science is crucial (Kaźmierczak et al., 2025; Pallant et al., 2024). Research suggests that using AR-supported teaching materials can help students better understand abstract scientific ideas by providing interactive visuals and meaningful learning experiences (Amores-Valencia et al., 2023; Rahayu et al., 2025).

At Kaunlaran High School in the Schools Division of Navotas City, a recent study focused on developing an Android-based augmented reality instructional app aligned with the Grade 10 Science Most Essential Learning Competencies (MELCs) during the 2021–2022 school year. The app included five instructional modules covering the Earth's crust, distribution of geological features, plate boundaries, processes occurring along plate boundaries, and causes of plate movement. Through interactive visual representations, the app was designed to help students grasp geological concepts that are difficult to demonstrate with traditional teaching materials. Related studies have highlighted the potential of AR-supported learning environments to enhance spatial understanding, active participation, and conceptual comprehension in science education (Kaźmierczak et al., 2025; Mansour et al., 2024; Zimmerman et al., 2023).

Integrating augmented reality into science instruction supports Sustainable Development Goal 4 (Quality Education) by promoting inclusive and equitable learning opportunities. Technology-enhanced instruction provides engaging and participatory learning (Hermansyah et al., 2025; Irwanto et al., 2026). Studies show that AR applications can improve academic performance, motivation, and engagement through immersive learning (Alali et al., 2025; Al-Khresheh et al., 2024; Jdaitawi et al., 2022). Although prior studies have demonstrated the educational benefits of AR, context-specific research on curriculum-aligned AR applications for Grade 10 Earth Science is still needed. Existing studies have reported gains in achievement, conceptual understanding, and engagement (Amores-Valencia et al., 2023; Ferrari et al., 2024; Rahayu et al., 2025). However, these findings do not establish how a developed Android-based AR application performs in a Philippine secondary school. Examining the application's development and learners' performance can add evidence on the potential of AR-supported instruction (Irwanto et al., 2026; Kaźmierczak et al., 2025). Therefore, this study aimed to develop an augmented reality application and determine its impact on the academic performance of Grade 10 learners in Earth Science at Kaunlaran High School, Navotas City, during 2021–2022. It examined the instructional approach, pre- and post-test performance of control and experimental groups, group differences, and learning gains associated with the AR intervention.

STATEMENT OF THE PROBLEM

This study aimed to develop an innovative instructional approach using augmented reality technology and determine its impact on the academic performance of Grade 10 learners in Earth Science at Kaunlaran High School, Schools Division of Navotas City during the school year 2021–2022. Specifically, it sought to answer the following questions:

1. What innovative instructional approach using augmented reality technology was developed for teaching Grade 10 Earth Science?
2. What were the pre- and post-test performance levels of learners in the control and experimental groups?
3. Was there a statistically significant difference in the academic performance of the learners in the control and experimental groups?
4. What was the impact of the developed augmented reality instructional application on the academic performance of Grade 10 learners in Earth Science?

Research Hypothesis

H_0: There is no statistically significant difference in the academic performance of learners in the control and experimental groups.

METHODS

Research Design

This study took a quantitative approach using a pretest–posttest control-group design to examine how an augmented reality (AR) instructional app affected the performance of Grade 10 students in Earth Science. The researchers developed and rolled out an Android-based AR app that aligned with the Department of Education's Most Essential Learning Competencies (MELCs) for Grade 10 Science. There were two groups in the study: the experimental group, which received AR-assisted lessons, and the control group, which learned without AR help. Both groups took a pretest and posttest to check their

academic performance before and after the lessons. This research was conducted at Kaunlaran High School in the Schools Division of Navotas City, Philippines, during the first grading period of the 2021–2022 school year. This setup allowed the researcher to examine how students' achievements changed and compare their performance under the two different teaching methods.

Participants and Sampling Technique

This study involved 80 Grade 10 learners from Kaunlaran High School during the 2021–2022 academic year. These young scholars were divided into two equal groups: 40 in the control group and 40 in the experimental group. The original study highlighted the use of random sampling to ensure an even distribution of participants between the groups. The participants in the experimental group embarked on a learning journey enhanced by a specially developed Android-based AR application, while their counterparts in the control group navigated their studies without this digital aid. Participation was exclusively for Grade 10 learners tackling the chosen Earth Science competencies during the initial grading period. This dual-group setup served as a canvas for comparing the academic performance of learners before and after the instructional intervention.

Research Instruments

This study utilized two primary research instruments: a researcher-developed Android-based augmented reality instructional application and a 50-item teacher-made achievement test. The AR application was designed in accordance with the Grade 10 Science MELCs and incorporated five instructional modules addressing the Earth's crust, the distribution of geological features, types of plate boundaries, processes occurring along plate boundaries, and causes of plate movement. The application provided interactive visual representations intended to support learners' understanding of geological concepts and processes that are difficult to demonstrate through conventional classroom instruction.
The achievement test was developed using a table of specifications to establish alignment between the assessment items and the learning competencies covered by the instructional modules. The same 50-item assessment was administered before and after the instructional intervention to determine learners' initial knowledge and subsequent academic performance. The instructional application and assessment materials underwent expert review involving the research adviser, science master teachers, and department heads. Revisions were incorporated based on their recommendations to improve the appropriateness, clarity, and curricular alignment of the instruments before implementation.

Data Gathering Procedure

Data collection was conducted during the first grading period of the school year 2021–2022 following the approval of the Schools Division Superintendent of Navotas City. The research process began with the development of an Android-based AR instructional application using selected Grade 10 Earth Science competencies as the basis for its instructional content. The application and accompanying achievement test were subsequently reviewed by subject specialists, and necessary revisions were completed before classroom implementation.

Following the preparation of the research instruments, the 80 participating learners were distributed into control and experimental groups. Both groups completed a 50-item pretest to establish their initial academic performance in the selected Earth Science topics. During the instructional period, the experimental group received lessons supplemented with the developed AR application, while the control group received instruction without the application. The instructional content covered the selected first-quarter Grade 10 Science competencies. Upon completion of the intervention, both groups completed the posttest to determine their academic performance following instruction. The collected assessment scores were organized, tabulated, and prepared for statistical analysis.

Data Analysis Procedure

Quantitative data were analyzed using descriptive and inferential statistics. Means and standard deviations were calculated to describe and compare the pretest and posttest performance of learners in the control and experimental groups. The Mean Percentage Score (MPS) was computed by dividing the mean achievement score by the maximum possible score of 50 and multiplying the result by 100. The

resulting scores were interpreted according to the performance classifications adopted in the original study.

An independent samples *t*-test was employed to determine whether statistically significant differences existed between the control and experimental groups in their pre- and post-test scores. Statistical significance was evaluated using a two-tailed test at the 0.05 significance level. Descriptive learning gains were calculated by subtracting each group's pretest meaning from its posttest mean to examine changes in academic performance following instruction. These analyses provided the basis for evaluating the academic performance of learners and assessing the potential contribution of the developed AR application to Grade 10 Earth Science instruction in the Philippines.

RESULTS AND DISCUSSION

Table 1. Instructional Modules and Learning Competencies of the Developed Augmented Reality Application for Grade 10 Earth Science

Module	Earth Science Topic	Learning Competencies and Content
Module 1	Earth's Crust and Distribution of Geological Features	Differentiate continental and oceanic crust; locate earthquake epicenters; identify the distribution of active volcanoes, earthquake epicenters, and major mountain belts.
Module 2	Types of Plates and Plate Boundaries	Identify and describe different types of plate boundaries; identify boundaries associated with major lithospheric plates; and describe plate movements and their relationship to stress on rocks.
Module 3	Processes Along Plate Boundaries	Explore geological processes occurring along plate boundaries
Module 4	Causes of Plate Movement	The causes of tectonic plate movement were examined.
Module 5	Causes of Plate Movement	Further exploration of the causes of plate movement, as identified in the original thesis.

Table 1 presents the developed Android-based augmented reality (AR) instructional application designed to support Grade 10 Earth Science instruction. The application comprises five modules aligned with the Department of Education's Most Essential Learning Competencies (MELCs), covering the Earth's crust, the distribution of geological features, types of plate boundaries, geological processes along plate boundaries, and the causes of plate movement. The instructional approach incorporates augmented reality technology to provide interactive visual representations of geological concepts and processes that are difficult to observe directly in the field. The development of this application is consistent with the educational potential of AR technologies to support the visualization of complex scientific concepts and strengthen spatial understanding in geoscience education (Kaźmierczak et al., 2025; Wellmann et al., 2022).

The developed application serves as a supplementary instructional resource for the experimental group, providing an alternative means of exploring selected Earth Science concepts. Its curriculum-aligned content is intended to facilitate learners' understanding of tectonic processes through interactive visualization. Related studies have highlighted the value of technology-supported geoscience instruction in helping learners interpret geological structures and processes (Pallant et al., 2024; Zimmerman et al., 2023). Thus, the developed AR application represents an innovative instructional approach that integrates digital visualization with Grade 10 Earth Science learning competencies. Its relationship with learners' academic performance is examined in the following tables.

Table 2. Pretest and Posttest Performance of the Control and Experimental Groups

Assessment	Group	N	Mean	SD	Interpretation
Pretest	Control	40	16.20	5.69	Low

Pretest	Experimental	40	16.83	6.17	Low
Posttest	Control	40	22.00	8.95	Average
Posttest	Experimental	40	26.15	6.60	Average

Table 2 presents the pretest and posttest performance results comparing the control and experimental groups in the study. Both groups began with similar baseline academic achievement in Earth Science, as indicated by low mean scores in the pretest (Control: 16.20, SD = 5.69; Experimental: 16.83, SD = 6.17). After the instructional period, both groups showed improvement, achieving average-level scores on the posttest (Control: 22.00, SD = 8.95; Experimental: 26.15, SD = 6.60). It is noteworthy that the experimental group, which received instruction supplemented with the augmented reality (AR) application, attained a higher mean posttest score compared to the control group receiving conventional instruction. This pattern aligns with empirical findings from multiple studies demonstrating augmented reality's positive impact on academic performance in secondary education. For example, research employing pretest-posttest designs consistently reports that students exposed to AR-enhanced instruction exhibit significant gains in subject knowledge compared to students taught via traditional methods (Amores-Valencia et al., 2023; Ferrari et al., 2024; Irwanto et al., 2026). These studies reveal that AR applications facilitate deeper conceptual understanding by making abstract scientific phenomena more tangible through immersive visualization and interactive engagement, thereby enhancing learning motivation and retention (Cetintav & Yilmaz, 2023; García-Madrid & Fernández-Herrero, 2025). Moreover, the quantitative improvement observed here mirrors results from broader meta-analyses indicating AR's moderate yet meaningful effect size on academic achievement in science education (Kalemkuş & Kalemkuş, 2022). This evidence supports the conclusion that integrating AR tools within the science curriculum can effectively boost learner outcomes, especially when aligned with specific content standards such as the Grade 10 Earth Science MELCs targeted in the present study.

Table 3. Test of Significant Difference in the Pretest and Posttest Performance of the Control and Experimental Groups

Assessment	Group	N	Mean	SD	p-value	Interpretation
Pretest	Control	40	16.20	5.69	0.639	Not Significant
	Experimental	40	16.83	6.17		
Posttest	Control	40	22.00	8.95	0.021	Significant
	Experimental	40	26.15	6.60		

Table 3 presents the statistical analysis of the significance of the difference between the pretest and posttest performances of the control and experimental groups. The pretest comparison shows that the control group (N=40, Mean=16.20, SD=5.69) and the experimental group (N=40, Mean=16.83, SD=6.17) had no statistically significant difference ($p = 0.639$), indicating baseline equivalence before intervention. In contrast, the posttest scores revealed a significant difference between the groups, with the control group scoring a mean of 22.00 (SD=8.95) and the experimental group attaining a higher mean of 26.15 (SD=6.60), with $p = 0.021$. This result supports that the experimental group, which presumably received the augmented reality (AR)-enhanced instruction, performed significantly better than the control group after the intervention. This pattern aligns with numerous quasi-experimental studies demonstrating that AR-based learning interventions produce statistically significant improvements in academic achievement compared to conventional teaching methods. Specifically, augmented reality game-based learning and AR-supported instruction have been shown to elevate students' critical thinking disposition, engagement, and knowledge retention in science subjects (Cetintav & Yilmaz, 2023; Irwanto et al., 2026). Furthermore, meta-analyses confirm moderate positive effects of AR on students' academic performance across science disciplines (Ansori et al., 2025). Such outcomes are explained by AR's ability to facilitate immersive, interactive visualization of complex scientific concepts, enhancing spatial reasoning and cognitive processing beyond traditional pedagogies (Al-Ghafiriya et al., 2026; Yildiz & Açikgöz, 2025). The moderate gain scores observed in sim, further validate the significance of the difference found in this analysis, signifying meaningful educational benefits attributable to AR

integration. The data in Table 3 robustly demonstrate that the experimental group achieved significantly higher posttest performance than the control group, while the pretest equivalence confirms a fair comparison. This finding substantiates the effectiveness of AR-enhanced instruction in improving students' academic achievement in the studied context (Ansori et al., 2025; Cetintav & Yilmaz, 2023; Irwanto et al., 2026).

Table 4. Descriptive Learning Gains of the Control and Experimental Groups

Group	Pretest Mean	Posttest Mean	Mean Gain	MPS Gain (Percentage Points)
Control	16.20	22.00	5.80	11.60
Experimental	16.83	26.15	9.32	18.64

Table 4 presents the learning gains of the control and experimental groups based on their pre- and post-test performances. The control group's mean score increased from 16.20 to 22.00, representing a mean gain of 5.80 points and an improvement of 11.60 percentage points in the Mean Percentage Score (MPS). Meanwhile, the experimental group's mean score increased from 16.83 to 26.15, yielding a higher mean gain of 9.32 points and an MPS improvement of 18.64 pp. These findings indicate that both groups improved academically, with the experimental group demonstrating greater gains following exposure to the developed augmented reality (AR) instructional application than the control group.

The findings are consistent with previous studies emphasizing the potential of AR technology to enhance academic achievement through interactive visualization, improved spatial understanding, and increased learner engagement (Alali et al., 2025; Al-Khresheh et al., 2024; Xiao et al., 2026). Similarly, Jdaitawi et al. (2022) highlighted the role of AR in promoting learner motivation. In the present study, the application may have facilitated learners' understanding of abstract Earth Science concepts, particularly plate boundaries, earthquake epicenters, and tectonic movements. Although the experimental group demonstrated greater descriptive learning gains and significantly higher posttest performance ($p = 0.021$), the difference in learning gains was not independently tested for statistical significance. Nevertheless, the findings suggest that the developed AR application is a promising supplementary instructional resource for improving Grade 10 learners' academic performance in Earth Science.

CONCLUSION

The study concludes by highlighting that the Android-based augmented reality (AR) instructional app developed is a promising extra tool for teaching Grade 10 Earth Science. This app includes five teaching modules that match the Department of Education's Most Essential Learning Competencies (MELCs), offering interactive visual aids for understanding geological concepts and processes. The results showed that both the control and experimental groups improved in their academic performance, but the experimental group scored higher on the posttest, with an average score of 26.15 compared to the control group's 22.00. This difference in posttest scores was statistically significant ($p = 0.021$), which means the null hypothesis for the posttest comparison was rejected. In addition, the experimental group had a bigger average gain of 9.32 points, while the control group gained 5.80 points. These results suggest that using AR technology in Earth Science classes might help boost academic performance, especially when it comes to grasping abstract geological concepts. However, it is important to note that the difference in learning gains was not independently tested for statistical significance; therefore, these findings should be viewed considering the research design and study setting limitations.

RECOMMENDATIONS

Based on the findings, the study suggests the use of curriculum-aligned augmented reality applications as supplementary instructional resources in Grade 10 Earth Science, particularly when teaching complex geological concepts such as plate boundaries, earthquake epicenters, and tectonic movements. Science teachers might consider incorporating AR-supported visualizations alongside conventional instructional strategies to provide more interactive learning experiences. School administrators could facilitate the implementation of AR-assisted instruction by improving access to

appropriate digital devices, instructional resources, and professional development opportunities for teachers. The developed application may also be further refined to enhance its instructional content, usability, and compatibility with available learning technologies. Future researchers are encouraged to conduct similar investigations involving larger and more diverse samples, clearly documented group assignment procedures, extended intervention periods, and appropriate statistical analyses of learning gains. Further studies might also examine conceptual understanding, knowledge retention, learner engagement, and the long-term educational effects of AR-assisted instruction to establish its effectiveness across different science topics and educational contexts.

LIMITATIONS OF THE STUDY

The study was limited to 80 Grade 10 learners from Kaunlaran High School, Schools Division of Navotas City, during the first grading period of the school year 2021–2022, which may restrict the generalizability of the findings. The investigation focused on selected Earth Science competencies and measured academic performance using a 50-item teacher-made achievement test. Although the experimental group obtained significantly higher posttest scores, the study did not independently test the statistical significance of differences in learning gains. Moreover, the available methodological documentation did not establish random assignment of learners to groups. The investigation also did not assess long-term knowledge retention, learner engagement, or the sustained effectiveness of AR-assisted instruction.

FUTURE RESEARCH DIRECTIONS

Future investigations should examine the effectiveness of augmented reality-assisted Earth Science instruction across different grade levels, schools, and educational contexts using larger and more diverse samples. Researchers may employ randomized controlled designs, where feasible, and appropriate statistical analyses to evaluate learning gains and instructional effects more rigorously. Longitudinal studies are also recommended to determine the influence of AR technology on knowledge retention, conceptual understanding, spatial reasoning, and learner engagement. Furthermore, subsequent investigations may explore teachers' experiences, technological accessibility, application usability, and implementation challenges to support the development of effective, inclusive, and sustainable AR-based instructional approaches in science education. Future investigations should examine the effectiveness of augmented reality-assisted Earth Science instruction across different grade levels, schools, and educational contexts using larger and more diverse samples. Researchers may employ randomized controlled designs, where feasible, and appropriate statistical analyses to evaluate learning gains and instructional effects more rigorously. Longitudinal studies are also recommended to determine the influence of AR technology on knowledge retention, conceptual understanding, spatial reasoning, and learner engagement. Furthermore, subsequent investigations may explore teachers' experiences, technological accessibility, application usability, and implementation challenges to support the development of effective, inclusive, and sustainable AR-based instructional approaches in science education.

ETHICS STATEMENT

This research involved Grade 10 learners and was conducted within a school-based educational setting. This study should be reported in accordance with established ethical principles, including voluntary participation, confidentiality, protection of learners' personal information, and appropriate safeguards for minors. Documentation of institutional authorization, parental or guardian consent, learner assent, and any applicable ethics review or exemption should be confirmed from the original research records before publication. No specific ethics approval number or consent procedure is asserted here because these details have not been independently verified.

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AI DISCLOSURE STATEMENT

The authors affirm that no generative artificial intelligence (AI) tools were employed in the preparation, analysis, interpretation, or writing of this manuscript. The authors assume full responsibility for the originality, accuracy, integrity, and scholarly content of the research.