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Technology-Supported Inquiry Learning for Primary Students: A Comparison of the 5E Model and Citizen Inquiry on Understanding and Attitudes

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Abstract

Inquiry-based pedagogy supported by digital tools has been increasingly recognized as a promising approach to strengthen students' conceptual understanding and engagement in science learning. However, limited research has examined how different inquiry frameworks function in technology-rich primary classrooms. This study aimed to compare students' understanding of water resources and conservation concepts and to examine their attitudes toward science learning with technology when taught through either the 5E model or Citizen Inquiry. A quasi-experimental design was conducted with 70 Grade 5th students across two groups. The findings indicated that both instructional approaches improved the students' conceptual understanding. Moreover, those who learned with the citizen Inquiry with technology demonstrated significantly higher post-test scores than those who learned with the 5E model with technology. In contrast, no significant differences were found in students' attitudes across five measured dimensions, although Citizen Inquiry showed a slight, non-significant advantage in affective engagement. These results suggested that the two approaches offer distinct strengths, and that hybrid instructional designs combining structured scaffolding with authentic participation may provide a balanced pathway for supporting both conceptual development and meaningful engagement in science classrooms.

Keywords: Inquiry-based learning, 5E model, Citizen Inquiry, technology integration, primary education

■ Introduction

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Inquiry-based learning has long been acknowledged as an effective pedagogical approach for fostering students' conceptual understanding, scientific reasoning, and engagement in authentic practices (Bell et al., 2009; Pedaste et al., 2015). With the increasing availability of digital technologies, inquiry frameworks in science education have been frequently supported by tools that scaffold investigations, provide access to authentic data, and facilitate collaboration (Chen, Zhang, & Chen, 2025; Blanchard et al., 2010). Technology-supported inquiry has been shown to advance both "learning through inquiry," which emphasizes the acquisition of conceptual knowledge, and "learning of inquiry," which develops inquiry skills, thereby offering a comprehensive foundation for improving science education (Chen et al., 2025; Soriano-Sánchez, 2025).

Among structured inquiry approaches, the 5E learning cycle—engage, explore, explain, elaborate, and evaluate—has received extensive attention for guiding students systematically through scientific processes. Prior research has demonstrated that structured designs, particularly when integrated with digital simulations and scaffolding tools, enhanced conceptual outcomes and sustained learner engagement (Rayan et al., 2023; Belland et al., 2019). In parallel, citizen science has emerged as a complementary approach for involving learners in authentic, real-world investigations. Citizen Inquiry, which combines the participatory features of citizen science with inquiry-based pedagogy, enabled students to contribute to data collection, environmental monitoring, and problem-solving activities, thereby strengthening connections between classroom learning and societal challenges (Roche et al., 2020; Tsivitanidou & Ioannou, 2020).

Existing evidence has indicated that these two approaches offer distinct strengths. Structured inquiry provided explicit scaffolding that supported conceptual development, whereas Citizen Inquiry enhanced learner ownership, motivation, and affective engagement with science (Berndt & Nitz, 2023; Buchanan, Pressick-Kilborn, & Maher, 2019). Nonetheless, their relative effectiveness in primary education has remained underexplored, particularly when digital technologies were integrated into classroom instruction. Few studies have directly compared structured and participatory inquiry frameworks in technology-rich learning environments, leaving important gaps in understanding how these approaches differentially shaped conceptual learning and student attitudes.

■ Significance and Purposes

This study was significant in advancing research on technology-supported inquiry learning in primary education. By comparing the 5E model with Citizen Inquiry, it generated insights into how different inquiry-based pedagogical structures function when integrated with digital tools. The 5E model emphasized structured phases of engagement and scaffolding, whereas Citizen Inquiry placed greater emphasis on learner participation and ownership. Examining the relative effectiveness of these approaches in technology-rich environments informed educators on how digital platforms could be combined with inquiry frameworks to optimize student learning outcomes.

Furthermore, the study contributed to the growing body of literature on the influence of technology integration on students' attitudes toward science learning. Positive attitudes toward technology use have been shown to be critical for sustaining engagement, enhancing digital confidence, and supporting long-term motivation. By analyzing students' responses to the two inquiry approaches in technology-supported contexts, the findings clarified which instructional designs fostered more favorable attitudes, thereby offering implications for curriculum development and instructional decision-making. The research purposes as follows:

1) To compare students' understanding of water resources and conservation concepts between the 5E learning with technology and the Citizen Inquiry learning with technology

2) To compare students' attitudes toward science learning with technology between the 5E learning with technology and the Citizen Inquiry learning with technology

■ Literature Reviews

Citizen Inquiry Learning in Science Education

Citizen inquiry learning, which integrated the participatory nature of citizen science with inquiry-based science education, received increasing attention for its potential to engage students in authentic scientific practices. This approach encouraged learners at the primary and secondary levels to take part in real-world investigations through data collection, environmental monitoring, and problem-solving activities. In doing so, it promoted deeper engagement and scientific literacy. Citizen science (CS) was widely recognized for its ability to bridge formal education and scientific practice. Roche et al. (2020) showed that CS provided learners with tangible experiences that connected everyday life with scientific processes. These experiences fostered lifelong learning and strengthened science engagement. They also argued that aligning educational goals with CS project aims through co-creation models ensured accessibility and inclusivity in project design and implementation.

Building on this perspective, Tsivitanidou and Ioannou (2020) emphasized the value of CS in K–12 settings, especially when supported by digital technologies. Their review of empirical studies indicated that although CS projects differed in the use of digital tools and levels of public involvement, they consistently offered authentic contexts for developing inquiry skills and evidence-based reasoning. They also helped students form more positive attitudes toward science. These findings aligned with broader calls for student-centered learning environments that linked classroom experiences with real-world socio-scientific issues. In this regard, citizen inquiry functioned both as a pedagogical strategy and as a means of strengthening students' science capabilities. Buntting, Moeed, and Anderson (2025), through a research–practice partnership in New Zealand, showed that online citizen science (OCS) projects embedded within broader learning units supported the development of five key capabilities: gathering and interpreting data, using evidence, critiquing evidence, interpreting representations, and engaging with science. Their study demonstrated that both contributory and co-created OCS projects encouraged student agency and curiosity when teachers provided appropriate scaffolding.

However, the effectiveness of citizen inquiry learning depended on the nature of student participation and project design. Berndt and Nitz (2023) conducted a quasi-experimental study to examine the effects of different levels of student involvement in CS projects. They found that all participants improved their content knowledge and environmental attitudes, yet the degree of involvement—from simple data collection to full co-creation—did not consistently predict learning outcomes. This indicated that the educational value of CS relied more on how it was integrated into teaching than on the extent of participation. Extending this view, environmental education research also supported the role of citizen inquiry in promoting sustainability values. Buchanan, Pressick-Kilborn, and Maher (2019) showed that digital technologies such as mobile applications, virtual environments, and videoconferencing enhanced student engagement in environmental learning. Their case studies with primary students revealed that these tools not only supported data collection and sharing but also deepened emotional connections with local ecosystems and increased motivation to take environmental action.

In sum, citizen inquiry learning represented a powerful approach for enriching science education through active and student-centered engagement in real scientific work. It offered particular promise for fostering scientific literacy, environmental stewardship, and digital competence. To realize this potential, however, educators needed to ensure thoughtful curricular integration, strong teacher support, and access to well-designed digital platforms.

Technology-Supported Inquiry Learning in School Science

Inquiry learning was widely recognized as an effective pedagogical approach for developing students' understanding, applying scientific concepts and methods (Bell et al., 2009). It engaged learners in processes such as asking questions, planning investigations, collecting and analyzing data, and drawing evidence-based conclusions (Pedaste et al., 2015). In school science, technology has increasingly been integrated to scaffold these processes, providing tools that facilitate authentic scientific practices and enhanced conceptual understanding. Research demonstrated that inquiry learning supported by technology fostered both "learning through inquiry," which focused on gaining scientific knowledge, and "learning of inquiry," which emphasized the development of inquiry skills (Chen, Zhang, & Chen, 2025).

Building on this foundation, digital platforms, simulations, and collaborative tools provided structured guidance and resources to support students through different phases of the inquiry process. For instance, environments such as the Web-based Inquiry Science Environment (WISE) and Physics Education Technology (PhET) simulations offered driving questions, resource libraries, and visualizations that helped students investigate scientific phenomena (Blanchard et al., 2010; Rayan et al., 2023). Structured inquiry models, in which investigation methods were predefined but results were left for students to interpret, were shown to improve learning outcomes (Belland et al., 2019; Chen et al., 2017). Extending these insights, technology-enhanced learning also incorporated adaptive features that personalized inquiry tasks, addressed individual learning needs, and fostered learner autonomy (Soriano-Sánchez, 2025). Prior studies showed that mobile learning improved students' conceptual understanding and learning achievement in science (Chu et al., 2010; Zacharia, Lazaridou, & Avraamidou, 2016), while Looi et al. (2009) reported that mobile environments promoted personalized and self-directed learning. A meta-analysis of 44 K–12 studies further revealed that mobile learning had a large positive effect on science education (g = 0.75), with particularly strong outcomes in primary education, environmental science topics, and semi-formal contexts such as museums or outdoor activities (Garzón & Lampropoulos, 2024). The analysis also indicated that situated and collaborative approaches generated the greatest benefits, showing that the affordances of mobile devices—portability, context sensitivity, immediacy, and connectivity—were most effective when aligned with constructivist pedagogies. Collectively, the evidence confirmed that mobile learning represented a robust pedagogical strategy for advancing science education by enabling authentic, interactive, and student-centered learning experiences.

Finally, evidence further suggested that technology-supported inquiry enhanced students' scientific literacy, subject knowledge, and attitudes toward science. In rural classrooms, collaborative inquiry supported by digital tools improved conceptual understanding and engagement, particularly when students with higher ICT proficiency used digital tools more effectively to generate richer discussions and more accurate data interpretations (Chen, Zhang, & Chen, 2025). In primary education, technology-enhanced science activities were linked to increased motivation when tasks connected to everyday life and cross-cultural contexts, with digital feedback and collaboration sustaining interest during both exploratory and synthesizing phases of learning (Ginzburg & Barak, 2023). Meta-analytic findings reinforced these benefits, indicating that ICT integration enhanced participation, motivation, and learning outcomes, especially when designed to be inclusive and adaptive to diverse learners (Soriano-Sánchez, 2025). Overall, the literature indicated that technology-supported inquiry held significant potential to advance science education by enhancing conceptual understanding, inquiry skills, and motivation, particularly when integrated with structured guidance, collaboration, and adaptive resources that addressed learner diversity.

■ Methods

This study employed a quasi-experimental research design with a non-equivalent control group pretest–posttest structure. This design was selected to compare the effects of technology-supported citizen inquiry learning and 5E instruction on primary students' conceptual understanding and attitudes toward science learning with technology.

Participants

The participants were 70 fifth-grade students aged 10 to 11 years from a public school in northeastern Thailand. They were divided into two groups of 35 students each, the experimental group (Citizen Inquiry with technology) and the control group (5E instruction with technology). Group assignment was carried out through purposive sampling to ensure comparable classroom contexts. All students had basic technological skills, but none had prior experience with digital tools in science learning. The school setting was appropriate for examining the introduction of Citizen Inquiry supported by technology since students were familiar with computer use but had little exposure to structured technology-enhanced inquiry.

Research Instruments

Two instruments were employed in this study to measure students' conceptual understanding and attitudes. The first instrument was a pretest and posttest conceptual assessment developed to evaluate students' conceptual understanding of water resources and water conservation. The test consisted of 15 multiple-choice questions, with each correct response awarded two points, yielding a maximum score of 30. The same version of the test was administered for both the pretest and posttest. To establish reliability, the test was analyzed using Cronbach's alpha coefficient in SPSS, which produced a value of .909, indicating a high level of internal consistency.

The second instrument was the Science and Technology Attitude Scale (STAS), originally developed by Pierce et al. (2007) and adapted for this study. The STAS is a 5-point Likert-scale questionnaire designed to assess students' attitudes toward science learning with technology. It comprises 20 items distributed across five subscales: scientific confidence (SC) (e.g., *I am confident with science*), attitude toward learning science with technology (ST) (e.g., *Science is more interesting when using digital tools.*), confidence with technology (TC) (e.g., *I am good at using technologies (such as sensors, google earth) in science*), affective engagement (AE) (e.g., *Learning science is enjoyable*), and behavioral engagement (BE) (e.g., *I try to answer questions the teacher asks*). Each subscale contains four items, providing a balanced measure of students' cognitive, affective, and behavioral orientations toward science and technology learning.

Designing Learning Process and Instruments

Teaching science through inquiry has been widely recognized as an essential pedagogical approach for fostering students' engagement in authentic scientific practices. Inquiry-based instruction allows learners to construct understanding by answering questions through data collection, analysis, and information exchange (Strat et al., 2023). To design the learning process for this study, the framework proposed by Buck, Bretz, and Towns (2008) was applied. This framework identifies six core characteristics of inquiry-based activities and experiments: (1) problem or question formulation, (2) background or theoretical grounding, (3) procedure or experimental design, (4) results analysis, (5) communication of findings, and (6) drawing conclusions. For this study, the instructional design emphasized Level 1 guided inquiry, in which the teacher provided the research problem and data collection procedures, while students independently conducted the analysis, communicated results, and formulated conclusions. This balance of guidance and autonomy ensured that learners received structured support while also engaging in higher-order thinking tasks.

Beyond guided inquiry, this study also incorporated the principles of citizen inquiry, which combines the knowledge development of inquiry-based learning with the participatory character of citizen science. Citizen inquiry enables learners, including those without prior scientific expertise, to participate in all stages of the scientific process—from defining research questions and setting objectives to collecting and analyzing data and communicating results. It has been described as an innovative pedagogical approach that draws on the strengths of citizen science, such as inclusivity, public participation, and authentic engagement with research. In this way, citizen inquiry provides opportunities for students to experience science as an evolving and collaborative practice rather than as a set of fixed facts (Herodotou et al., 2018). Although rooted in citizen science, citizen inquiry has increasingly been regarded as a versatile educational model applicable across multiple disciplines, including the social sciences and humanities. In this study, it was used to empower primary students to engage with environmental issues directly connected to their everyday lives.

To implement guided inquiry and citizen inquiry, a series of classroom activities supported by digital technologies was designed. Figure 1 presented the technology-supported Citizen Inquiry process aligned with the guided inquiry stage and clarified teacher and student roles at each stage. In the Problem/Question stage, the teacher introduced a real-world scenario (e.g., drought impacts) and stimulates curiosity, while students formulate guiding questions. During the Theory/Background stage, the teacher provided contextual resources (e.g., Google Earth) as students identify relevant water sources and generate hypotheses. In the Procedures/Design stage, the teacher scaffolded the use of digital tools (e.g., sensors, mobile applications) as students conduct data collection collaboratively. In the Result Analysis stage, the teacher models analytical strategies while students independently interpret patterns using spreadsheets. In the Communication stage, the teacher facilitateed reflection, and students present findings on digital platforms (e.g., Padlet). Finally, in the Conclusion stage, teachers guided synthesis of learning outcomes, while students express personal reflections and implications.

The instructional process was carefully sequenced to guide students through the inquiry process while providing opportunities for autonomy. At the beginning of each class, the teacher introduced a real-world scenario related to water quality to stimulate interest and initiate the problem/question stage. This was followed by background instruction and a demonstration of Google Earth to identify local water sources. The teacher also explained the use of technology tools, including the pH sensor and color detection application, before students began their fieldwork. During the procedures stage, students collaborated in small groups to collect data at nearby water sources. Once data had been gathered, they entered their findings into a Google Spreadsheet and, with teacher guidance, analyzed the results to address the inquiry question. The stage concluded with students drawing conclusions from their analysis and communicating results to peers using Padlet. Through this design, the integration of guided inquiry, citizen inquiry, and digital technologies created a learning environment that reflected authentic scientific practice. Students not only engaged in systematic processes of data collection and analysis but also participated in collaborative communication and reasoning.

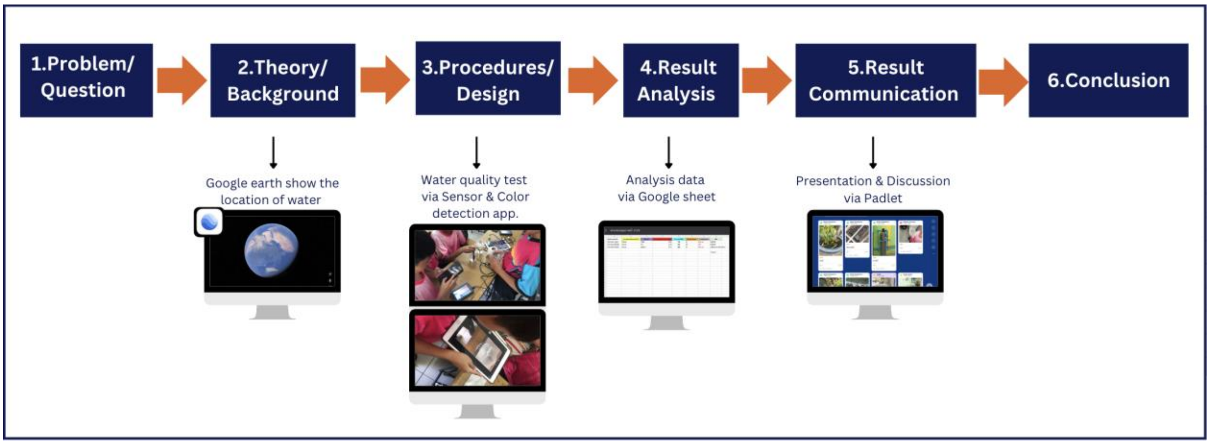

Figure *1*. The technology-supported citizen inquiry learning process on the theme of water quality detection

Data collection Procedures

This study was a quasi-experimental design to investigate the effectiveness of citizen inquiry learning supported by digital technologies in enhancing students' conceptual understanding of water resources and water conservation, and attitudes towards learning science with technology. Both groups of students initially completed a pre-test measuring their understanding of water resources and water conservation concepts, as well as their attitude toward science learning with technology, which required approximately 40 minutes to complete. Subsequently, the control group received conventional instruction on water resources and water conservation using a 5E inquiry learning approach with digital technologies, while the experimental group engaged in a series of Citizen inquiry learning activities. The intervention spanned two weeks, with a total instructional time of 240 minutes.

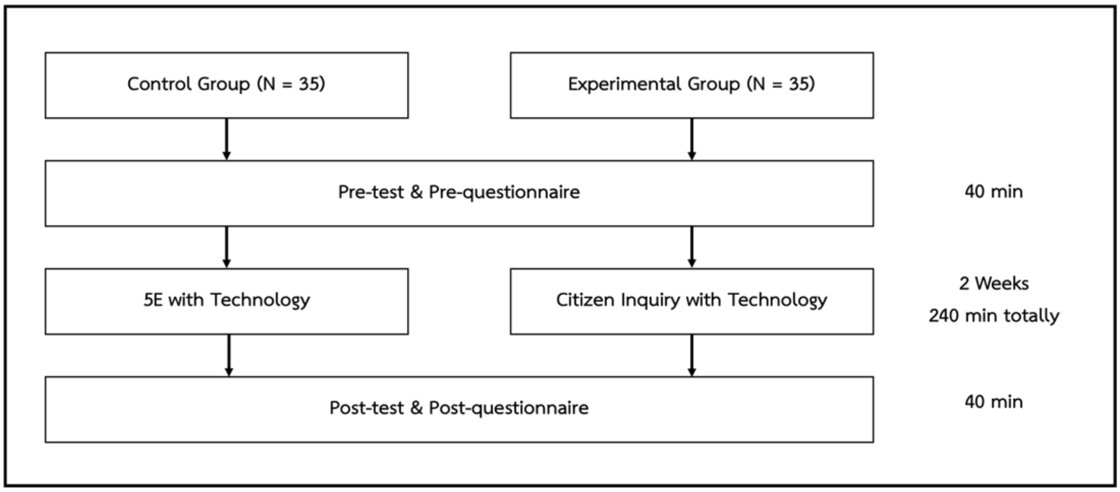

Figure *2*. the data collection process.

For the control group, the instructional approach followed the 5Es inquiry model (Engage, Explore, Explain, Elaborate, and Evaluate) combined with digital tools as showed in figure 3. In the Engage phase, the teacher introduced the topic by greeting students and stimulating curiosity through a decoding picture game. This activity was followed by showing a short video clip about drought impacts in Thailand, after which students were prompted with questions such as “What problems did you see in the video?” and “What might cause droughts that reduce our water supply?” These prompts encouraged students to connect personal observations with the broader issue of water scarcity. During the Explore phase, students used the Google Earth application to investigate the proportions of land and water on Earth. Guiding questions directed students to consider the relative distribution of oceans and continents. The teacher then grouped students into teams of five to six and introduced various examples of global and local water sources, such as the Chao Phraya River, Bueng Kaen Nakhon, groundwater, and the Dead Sea. Each group was tasked with classifying these examples as surface water or groundwater, and with searching online to determine their uses. Students recorded their findings on an application sheet, thereby engaging in collaborative inquiry and information gathering.

Figure *3*. Illustration of students' interaction with technology integrated into the 5E learning approach

The Explain phase was led by the teacher, who presented a slide-based explanation to consolidate the students’ exploratory findings. This ensured conceptual clarity regarding the types of water sources and the distinction between fresh and saltwater resources. In the Elaborate phase, the inquiry was extended to the students’ immediate environment. The teacher provided examples of water sources within the school, such as the swimming pool and hand-washing stations. Students were guided by questions including: “Is this source fresh or saltwater?”, “Is it surface or groundwater?”, and “How is it used in the school or community?” Each group then analyzed a specific local source, recorded findings on the application sheet, and discussed issues of maintenance and sustainability. This stage encouraged application of knowledge to real-world contexts and promoted environmental awareness. In the Evaluate phase, student understanding was assessed through the analysis of their group worksheets and through teacher observation of participation and behavior during activities. This evaluation captured not only knowledge outcomes but also collaborative and inquiry skills.

Figure *4*. Illustration of students' interaction with technology integrated into Citizen inquiry learning about water resources and water conservation concepts.

Meanwhile, the experimental group applied the Citizen Inquiry (CI) framework, which situates students as active participants in inquiry while connecting classroom science to real-world and community contexts as showed in figure 4. The instructional sequence comprised six stages. In the Problem/Question stage, the teacher began by greeting students and introducing the topic through a decoding picture game to stimulate curiosity. A short video on drought in Thailand was then shown, after which students were asked to identify the problem in the news and to consider its possible causes. Guiding questions encouraged them to link water scarcity to broader issues such as climate change, excessive water use, and the limited availability of freshwater. In the Theory/Background stage, students explored global water distribution using Google Earth. Through guided questioning, they compared proportions of land and water and discussed the distinction between surface and groundwater sources. The teacher extended their background knowledge by providing examples such as the Chao Phraya River, Bueng Kaen Nakhon, groundwater, and the Dead Sea, prompting students to consider their uses and societal relevance. A question was posed: “If the Earth contains such a large quantity of water, why do we still face water shortages?” This discussion led to an explanation of how only a small fraction of water is available as usable freshwater.

The Procedures/Design stage focused on local inquiry. Students were organized into small groups (4–5 members) and assigned to investigate actual water sources within the school environment, such as taps, ponds, or water tanks. Each group used an application sheet to record observations and uploaded photographs to a Padlet platform. Guiding questions directed them to identify whether each source was fresh or saltwater, surface or groundwater, and to evaluate its uses, maintenance, and potential problems. In the Result Analysis stage, groups collaboratively analyzed their findings. The teacher guided them to consider questions such as: “Who relies on this source?”, “What problems affect its sustainability?”, and “Why is maintenance important for long-term use?” Students’ analyses covered types of sources, their uses, issues observed, and suggestions for improvement.

The Result Communication stage required students to transform their findings into posters summarizing local water sources, their benefits, and sustainability concerns. These posters, created with digital tools of their choice, were presented via the Padlet platform, allowing for both in-class sharing and a broader digital record of student inquiry. In the Result Conclusion stage, individual students wrote short reflective notes on Padlet, such as what they had learned about the importance of school water sources and how they could contribute to their care. This encouraged personal responsibility and linked scientific learning to everyday civic action. After completing the learning process, both the control group and experimental group participated in the post-test to evaluate conceptual understanding using the same assessment for 30 minutes, followed by the attitude assessment for 10 minutes.

Data Analysis

For conceptual understanding, the Mann–Whitney U test was applied to compare the groups. Both groups were equal in size but the preliminary normality tests revealed violations of the assumptions required for parametric analysis. The Shapiro–Wilk test showed significant deviations from normality in several distributions (e.g. pre-test in control group (p = .018) and post-test in experimental group (p = .043)). Consequently, the Mann–Whitney U test was selected due to the non-equivalent group design and these deviations from normality (Field, 2013).

For students' attitudes toward science learning with technology, a one-way multivariate analysis of variance (MANOVA) was conducted to examine group differences across the five subscales. All the data were analyzed using the IBM SPSS version 27.

■ Results and Discussion

Conceptual Understanding of Water Resources and Conservation

To address the first research purpose, which was to compare students' understanding of water resources and conservation concepts between the 5E learning with technology (control group) and the Citizen Inquiry learning with technology (experimental group), pre-test and post-test scores were analyzed using the Mann-Whitney U test.

Table 1.

The Mann-Whitney U Test Results of the Scientific Concept on Water Resources and Conservation

Test	Experimental group			Control group			z	p-value
	N	$\bar{x}$	S.D.	N	$\bar{x}$	S.D.		
Pre-test	35	14.86	4.34	35	14.94	5.44	-.471	.638
Post-test	35	21.17	5.08	35	18.00	6.12	-2.193	.028*

*A significant level of $p<.05$

As shown in Table 1, the pre-test scores indicated that the two groups began the study with comparable levels of prior knowledge, as no significant differences were detected. This confirmed that both groups were equivalent at baseline. Following the intervention, the experimental group that participated in the Citizen Inquiry activities demonstrated significantly greater gains in conceptual understanding score than the control group taught with the 5E approach. The magnitude of the difference reflected not only higher mean scores but also a more consistent pattern of achievement across students in the experimental group. These findings indicate that although both groups improved after the intervention, students in the Citizen Inquiry condition demonstrated significantly greater gains in conceptual knowledge of water resources and conservation than those in the 5E condition.

The results suggested that Citizen Inquiry supported by digital tools was more effective in promoting conceptual understanding of water resources and conservation than the 5E learning model. Although both groups began with similar levels of prior knowledge, the participatory nature of Citizen Inquiry appeared to foster stronger learning outcomes. This finding extends previous studies, which have highlighted the potential of inquiry approaches that combine authentic participation with structured scientific practices to enhance student learning (Roche et al., 2020; Tsivitanidou & Ioannou, 2020). The opportunity for students to actively contribute to data collection, analysis, and communication of results may have encouraged deeper engagement and knowledge construction.

In contrast, the 5E model emphasizes structured phases of engagement, exploration, explanation, elaboration, and evaluation. Prior research has shown that such scaffolding can strengthen conceptual understanding (Belland et al., 2019; Chen et al., 2017). However, the structured format in this study may not have provided the same degree of ownership and active participation as Citizen Inquiry, potentially limiting the depth of conceptual gains. Berndt and Nitz (2023) argued that the educational value of citizen science depends not only on participation but also on the way learning activities are embedded within classroom contexts. The present findings suggested that when digital tools are integrated into Citizen Inquiry, they may offer younger learners' meaningful opportunities to engage with complex environmental concepts.

These findings also align with broader research on the role of technology in supporting inquiry learning. Digital platforms, sensors, and collaborative tools have been shown to facilitate student learning by scaffolding data collection, analysis, and communication processes (Blanchard et al., 2010; Rayan et al., 2023). In this study, the combination of Citizen Inquiry with digital tools may have created conditions that reinforced authentic engagement while also supporting the development of scientific concepts. At the same time, the results do not reduce the potential benefits of the 5E model, which mentioned in earlier studies

(Buchanan, Pressick-Kilborn, & Maher, 2019). It can be used for particularly effective in sustaining engagement and providing structured pathways for concept development.

Students' Attitude toward Learning Science with Technology.

The second research purpose was to compare students' attitudes toward learning science with technology between the experimental group (5E learning with technology) and the control group (Citizen Inquiry learning with technology). A one-way MANOVA was conducted to examine whether students' attitudes toward learning science with technology differed between those groups. The multivariate test indicated that the effect of group was not statistically significant (Wilks' Lambda = .945, $F(5,64) = 0.74$, $p = .597$, $\eta^2 = .055$). This implied that the instructional approach did not produce a meaningful multivariate difference across all the attitude dimensions.

Table 2.

The one-way MANOVA Results of Comparing the Attitude toward Learning Science with Technology

Scale	Experimental group		Control group		F	η^2	p-value
	$\bar{x}$	S.D.	$\bar{x}$	S.D.			
SC	16.63	2.07	16.51	2.17	.051	.001	.823
ST	17.40	2.02	17.17	2.31	.195	.003	.660
TC	17.77	1.65	17.57	2.31	.222	.003	.639
AE	18.23	1.35	18.66	1.55	1.517	.022	.222
BE	16.87	1.78	16.86	2.00	.004	.000	.950

*A significant level of $p<.05$

As shown in Table 2, the multivariate analysis of post-intervention attitudes revealed no statistically significant differences between the two instructional groups across the five measured dimensions (scientific confidence (SC), attitude toward science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE)). Both groups reported similarly positive attitudes, indicating that exposure to technology-enhanced inquiry, regardless of framework, was sufficient to cultivate favorable perceptions of science learning. Particularly, the Citizen Inquiry group demonstrated a slight increase in affective engagement, although this difference did not reach statistical significance. Likewise, the two groups performed nearly identically in behavioral engagement. Taken together, these results indicate that both instructional approaches fostered comparable attitudes toward learning science with technology, with no meaningful differences across the five attitudinal dimensions.

The results revealed no statistically significant differences between the two groups across any dimension, suggesting that both instructional models fostered similarly positive attitudes toward learning science with technology. This finding was consistented with earlier studies showing that technology integration was often the main factor driving students' motivation and engagement, rather than the specific inquiry structure. For example, Tsivitanidou and Ioannou (2020) reported that citizen science projects enhanced students' attitudes toward science regardless of project design, while Ginzburg and Barak (2023) found that technology-enhanced science activities increased motivation when connected to everyday contexts. Likewise, a meta-analysis by Soriano-Sánchez (2025) confirmed that ICT integration in inquiry settings generally improved participation and engagement, particularly when tasks incorporated collaboration and digital feedback.

Interestingly, the Citizen Inquiry group showed slightly higher affective engagement than the 5E group although there were no statistically significant revealed. This result is consistent with earlier research suggesting that authentic and real-world contexts in citizen science projects can strengthen students' emotional connection to science (Buchanan et al., 2019). In this study, the affective advantages of Citizen Inquiry complemented its conceptual strengths, indicating that the two approaches contributed in different ways to science learning. Citizen Inquiry was more effective in improving conceptual understanding and also encouraged greater, though non-significant, emotional engagement. While, The 5E model offered structured guidance that supported students in organizing and processing their learning systematically.

■ Conclusion

This study compared the effects of two technology-supported inquiry approaches, 5E learning with technology and Citizen Inquiry learning with technology, on primary students' understanding of water resources and conservation concepts and their attitudes toward science learning with technology. The findings revealed that while both approaches enhanced students' learning, the Citizen Inquiry model led to significantly greater gains in conceptual understanding. The participatory and authentic nature of Citizen Inquiry, when combined with digital tools, appeared particularly effective in enabling young learners to engage deeply with complex scientific ideas. In contrast, students' attitudes in five areas which consisted of confidence in science, attitudes toward learning science with technology, confidence in using technology, emotional interest, and participation—did not show any significant differences between the two groups. Both teaching methods helped students develop positive attitudes toward learning science with digital tools. Citizen Inquiry showed a small but non-significant advantage in emotional interest, suggesting that real and participatory learning contexts may help students build stronger emotional connections to science.

Overall, the results highlight the complementary strengths of structured and participatory inquiry frameworks. Citizen Inquiry proved more effective in advancing conceptual knowledge, while the 5E model offered structured scaffolding that supported step-by-step of learning. This research contributed to the field of technology-supported inquiry learning in three key ways. First, it provided empirical evidence from a direct comparison of two widely discussed inquiry frameworks, the 5E model and Citizen Inquiry, when integrated with digital tools in primary science education. While earlier studies often examined these approaches separately, this study clarified their respective strengths in conceptual and attitudinal domains. Second, the findings emphasized the value of authentic participation in promoting conceptual understanding, while also reaffirming the importance of

5E learning approach. Third, the study extended existing literature by focusing on water resources and conservation, a socio-scientific issue of global importance, thereby showing how inquiry frameworks combined with technology can both enhance learning outcomes and foster the development of attitude toward science learning with technology of the primary students.

■ Implications and Limitations

Implications for Research and Practice

Taken together, the findings highlighted the complementary strengths of structured and participatory inquiry approaches in technology-supported science education. The Citizen inquiry with digital tools offered a powerful framework for advancing conceptual understanding, while 5E model revealed less effective for immediate knowledge gains about water resources and conservation. For practitioners, these results suggest that integrating the strengths of both models by combining structured scaffolding for concept mastery with authentic inquiry experiences for engagement may represent a promising pathway for designing balanced science curricula.

For researchers, the study emphasized the need to further examine the interplay between structured and open inquiry designs in technology-rich environments, particularly in primary education, where students' inquiry skills are still developing. Future work could explore hybrid designs that embed structured inquiry phases within authentic citizen science contexts, as well as longitudinal studies that track not only conceptual outcomes but also affective and behavioral changes over time.

Limitations

This study was limited by its focus on short-term learning outcomes within a single topic area and grade level. While the findings provided evidence of differential effects between 5E and Citizen Inquiry, broader generalization requires replication across diverse science topics, age groups, and cultural contexts. Additionally, attitudinal measures captured students' perceptions at a single point in time. Therefore, future research could benefit from mixed-method approaches, such as interviews or learning analytics, to capture more nuanced shifts in engagement and motivation.

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