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USING DIGITAL TECHNOLOGY TO FOSTER THE DEVELOPMENT OF PRIMARY SCHOOL PUPILS' UNDERSTANDING OF SCIENTIFIC INQUIRY: A CASE STUDY OF SCHOOLS IN GWAGWALADA AREA COUNCIL OF THE FEDERAL CAPITAL TERRITORY, ABUJA

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Abstract

The need to help learners develop scientific proficiency and have identified informal learning environments, interactive technologies, and an understanding of inquiry as ways to support this development has been underscored as critical for the national scientific agenda. The enhancing environmental knowledge package was developed in response to this need. The package is a digitally supported, inquiry-oriented learning package and focuses on engaging primary school pupils in science practices in formal and informal settings. This study employed a mixed methods approach to explore how engagement in the project affected 46 primary five pupils' views of scientific inquiry and if pupils' participation shaped certain aspects of scientific inquiry. The Views of Scientific Inquiry – Elementary School Version (VOSI-E) Instrument, was adapted and administered before and after pupils had engaged with a three-week enhancing environmental knowledge package and assessed aspects including the role of questions, diversity of methods, experiments and investigations, developing scientific explanations, supporting scientific explanations, predictions and hypotheses, role of subjectivity, role of creativity, and goal of science. VOSI-E responses were analysed using a mixed-methods approach. Chi-squared test results suggest that classroom learning coupled with visits to a wildlife center can help improve pupils' understanding of scientific inquiry when integrated with technology-enhanced, field-based inquiries that emphasise the practices of science.

Introduction

To understand and apply science, learners must master scientific processes and conduct investigations (Zeidan & Jayosi, 2015). The Nigerian basic science and technology curriculum incorporates a three-dimensional science education approach encompassing core ideas, crosscutting concepts, and scientific practices (Egbujuo, 2014). These dimensions facilitate learners' autonomous learning and advancement across four aspects of scientific proficiency: a) understanding, utilising, and interpreting scientific explanations; b) producing and assessing scientific evidence and explanations; c) comprehending the nature and progression of scientific knowledge; and d) engaging effectively in scientific practices and discourse (Gizaw & Sota, 2023).

Two additional strands of proficiency, specific to informal settings, help to foster affective dimensions of learning through: e) engagement and motivation of pupils to study about natural phenomena by providing them with experiences in the physical world; and f) the development of science learning identities as pupils are put in the position of scientists allowing them to practice the processes of science (Bell, Lewenstein, Shouse, & Feder, 2009). One of the more direct ways of engaging pupils in three-dimensional “knowledge-building processes that are the core of science” (Duschl, 2008, p. 269) to develop their proficiency in science is to engage them in inquiry. According to Vo and Simmie (2024), inquiry involves activities that mirror authentic scientific practices. Pupils engage with resources like literature, people, and environments to generate or answer questions and solve problems. Furthermore, as expressed by Schwartz et al. (2023), scientific inquiry is essential to scientific literacy, involving practices, epistemology, and real-world application and context. Inquiry, however, has not been prominent in many Nigerian schools where teachers still deploy the old conservative approach to engage pupils in science and science learning. Teachers' Common difficulties in incorporating scientific inquiries into their lessons include time constraints, pressures to meet curriculum requirements, lack of resources and support, and limited in-service training (Reiss et al., 2023).

Mat Noor, M. S. A. (2023) identifies four types of inquiry that offer different opportunities for pupils to engage in learning science content and process skills. These are: a) confirmation inquiry – where pupils verify a principle through an activity with known results; b) structured inquiry – where the teacher provides questions or problems along with prescribed procedures for pupils to follow; c) guided inquiry – where the teacher presents a question or problem and pupils choose or design the procedures to address it; and d) open inquiry – where pupils devise their questions or problems and methods for solving them. Regardless of the type of inquiry, there has been a trend to offer learners various learning opportunities (Pareto, Pettersson, and Söderberg, 2023). These opportunities span both formal classroom environments and informal settings, such as museums and wildlife parks (Erdyneeva et al., 2024) to develop “habits of mind” (American Association for the Advancement of Science, 1993, p. 281) associated with inquiry.

According to Dawson (2014), informal science education (ISE) can be broadly defined as "science education that occurs in out-of-school environments" and is gaining increased attention within the field of science education research. Science teaching that incorporates informal science experience allows learners to observe and interact with natural phenomena, encouraging them to ask questions, make observations, and develop critical thinking skills (Kiraga, 2023). Through engagement in informal settings, pupils gain a deeper understanding of scientific concepts, learn about the scientific method, and develop a sense of environmental responsibility (Zidny et al., 2020). Thus, informal environments allow pupils to engage in scientific inquiry through authentic real-world phenomena experiences (Looi et al., 2016). Learning in these environments can combine affective and cognitive learning, integrate education and recreation, and involve students in activities such as identification, observation, and imagination without the pressure of classroom norms.

Interactions in informal settings facilitate the integration of prior knowledge with new information and experiences more rapidly, thereby creating stronger and novel associations (Erdyneeva et al., 2024). These connections, nevertheless, are hindered when visits are not closely integrated with classroom activities (Avraamidou & Roth, 2016; Zimmerman & Land, 2017). Suppose pupils lack familiarity with aspects of scientific inquiry before their informal learning experiences. In that case, they may find it challenging to make connections in these environments (Foo & Foo, 2022), potentially decreasing the effectiveness of classroom instruction and field trip activities. In 2012, Morag and Tal interviewed participants from 22 schools and found that only 27% of schools had prepared their fourth through sixth-grade pupils in advance for their trip to a nature park and that only 5% had connected the trip to the school curriculum. It is important to note that even when teachers attempt to create a direct connection between field trips and the curriculum contents, the result is not constantly engaging. In a study conducted by Kisiel (2003) on teacher-led field trips to a natural history museum in Los Angeles, it was observed that only 7% of the groups had pre-planned pupil projects. Similarly, Holmes (2012) utilized pre- and post-reports to evaluate the activities teachers had arranged before, during, and after visits to a children's museum focused on math and science. While more than half of the teachers had their pupils complete reading assignments, watch educational videos, or carry out experiments prior to their museum visit, fewer than 20% engaged their pupils in any activities during the museum visit. Furthermore, many teachers lack specific follow-up lesson plans to link museum field trip learning with the curriculum or post-visit activities (Souza, Bonifácio & Rodrigues, 2022).

Integrating technology into field trip experiences to engage students and support their science learning can provide immediate stimuli to a technologically advanced generation (Chen, Chan, Huang, and Liao, 2022). Many researchers have investigated using interactive technologies and mobile computers to improve educational experiences in informal learning environments (Arici, 2024; Economou & Meintani, 2011; Proctor, 2011). While progress has been made in evaluating these technologies for informal learning, not many studies have been conducted on how the incorporation of technologies in informal learning can encourage active pupil engagement or support science practices and the development of science process skills.

This study aimed to investigate the learning outcomes of primary school pupils who participate in a digitally supported curriculum that engages them in scientific practices and skills both within the classroom and in informal settings.

Research Questions

The following questions were raised to guide the study:

- How do primary school pupils' perspectives on scientific inquiry evolve when they participate in a digitally supported, scientific inquiry-based curriculum both in the classroom and in informal environments?
- What are the most challenging aspects of scientific inquiry for pupils to learn in a digitally supported, inquiry-based curriculum both in class and informal settings?

Methodology

The research questions were explored before and after a set of five primary 5 pupils had engaged in a school-based project which sought to enhance learners' environmental knowledge for the preservation of the ecosystem. The learners were exposed to the curriculum package through their teachers for three weeks. 46 learners from intact classes in the four schools who volunteered to participate in all the project's learning activities were used to evaluate the impact of the curriculum package. The teachers, who have taught these pupils for more than 3 years, were given one week of orientation and training on the project by the researcher. After the training, the researcher interacted with the teachers on two critical aspects of the project and the enquiry method. The two days after training ensured that the teachers had developed an in-depth understanding of the project and the delivery method. The project utilized online and mobile learning technologies while learners conducted inquiries in the classroom and during a field trip to the National Children's Park and Zoo in Abuja. During the three-week package designed to enhance environmental knowledge, pupils participated in many activities that relied on traditional paper-and-pencil methods. However, technology was integrated into the Conducting a Scientific Investigation lesson to support pupils. Specifically, technology facilitated the development of their own research questions, supported the formation of scientific explanations, and prompted them to consider the role of subjectivity in conducting scientific investigations. On the first day of the Conducting a Scientific Investigation lesson, pupils researched the zoo's animals and habitats and examined data. This preparation helped them develop their research questions and methods. During the field trip, pupil groups used iPads to collect observational data and create new questions from their observations of the animals and the habitat. When they returned to the classroom, they analyzed their data and that of others to support their claims to answer the research question(s) they had generated. Each group then presented their findings through a poster or PowerPoint presentation. Pre- and post-responses to an open-ended questionnaire adapted from Schwarz, Lederman, and Lederman (2008) called "The Views of Scientific Inquiry - Elementary School Version (VOSI-E) were evaluated using a mixed methods approach. The researcher analyzed the VOSI-E by categorizing pupils' responses into naïve, transitional, or informed levels across nine scientific inquiry aspects. The frequency of word occurrences by level and aspect of scientific inquiry was analyzed to address each research question. For research question 1, overall changes in pupils' views on scientific inquiry were evaluated using level tallies before and after the study. For research question 2, changes in pupils' responses about each aspect were assessed using tallies by specific aspects of scientific inquiry.

Forty-six (46) primary 5 pupils and four teachers from four public schools in the Gwagwalada Area Council participated in the study. The schools used for the study represented both rural and urban settings, serving a diverse group. The teachers involved had over five years of experience.

The adapted VOSI-E questionnaire (Schwartz et al., 2008) was employed to evaluate pupils' understanding of scientific inquiry concepts three days before and three days after the study period. The open-ended format allowed pupils to articulate their conceptions freely, without imposing any predefined views, unlike the Likert scale or multiple-choice instruments. This survey featured two open-ended questions and two multi-part open-ended questions about the role of questions, diversity of methods, experiments vs. investigations, developing scientific explanations, predictions and hypotheses, subjectivity and creativity, and the goals of science. Pupils were told the aim was to understand their views on science and its processes, that some questions had multiple parts, that there were no right or wrong answers, and that they could draw pictures to explain their ideas. Questions 1 and 2 asked learners about the types of work scientists do and to describe this work. Questions 3 and 4 described a study of beak shape and food preference, asking learners if they believed the work was scientific and experimental. Pupils were asked to explain their answers after two questions. Questions 5a, 5b, and 6 addressed why dinosaurs died, asking if scientists would all agree on the cause, to justify their answer, and to identify the information used by scientists. The survey took about 30 minutes to complete.

Due to the open-ended nature of the VOSI-E responses, it was necessary to both qualitatively interpret and quantitatively score the data. The researchers utilised a three-level scoring rubric explicitly developed for this study, comprising naïve, transitional, and informed levels. This rubric guided the process of coding the research data based on the words or terms provided by pupils in response to open-ended questions. Each word or term was treated as an instance, and the use of a standardized scoring rubric enabled quantitative analysis while ensuring consistency across the coding process among the researchers. Pupils' responses were evaluated based on the quality and depth of information. A score of one (1) was assigned to naïve views of scientific inquiry, indicating a fundamental understanding of concepts. Transitional views received a score of two (2), reflecting a moderate level of understanding. Informed views were awarded a score of three (3), signifying a well-developed comprehension of the concepts. The researcher and a trained research assistant independently scored the VOSI-E answers with a Cohen's kappa inter-rater reliability of 0.74. A 2x3 contingency table of chi-square test was used to check for significant differences between pre- and post-survey scores.

Results

Before the study, pupils' VOSI-E scores showed mostly naïve views on scientific inquiry (Table 2). The pre-survey recorded 945 naïve, 173 transitional, and 7 informed responses. After participating in the study, pupils' understanding improved significantly ($\chi 2$ (1, N=2250) = 51.10, p < .001, Φ=.15), although the practical significance was low. Post-survey results showed 814 naïve, 278 transitional, and 33 informed responses (see Table 1).

Table 1. Changes in pupils' views of scientific inquiry

VOSI-E	Naïve	Transitional	Informed
Pre-survey	857	169	9
Post-Survey	714	268	43

Table 2: Changes observed in pupils' responses about aspects of scientific inquiry

		$\chi 2$	df	P	Φ
1	Role of Questions	13.36	2	< .001	.24
2	Diversity of Methods	5.69	2	.04	2.16
3	Experiments and Investigations	7.28	2	.03	.17
4	Developing Scientific Explanations	6.22	2	.01	.16
5	Supporting Scientific Explanations	26.08	2	.001	.32
6	Predictions and Hypotheses	*	---	---	---
7	Role of Subjectivity	11.37	2	.003	.21
8	Role of Creativity	1.00	2	.32	---
9	Goal of Science	1.91	2	.17	---

N- 46 *no change between pre- and post-test Cramer's Φ effect size range: .10 is small, .30 is medium, .50 is large (Volker, 2006).

There were significant differences in pupils' understanding before and after instruction across six aspects: roles of questions, diversity of methods, experiments and investigations, developing scientific explanations, supporting scientific explanations, and the role of subjectivity. Pupils initially exhibited predominantly naïve views in each of these areas. Notably, only subjectivity had a substantial number of transitional responses compared to naïve and informed responses before the intervention. No changes were found in pupils' understanding of predictions and hypotheses, the role of creativity, and the goal of science. Predictions and hypotheses, along with the role of creativity, had very few or no pupils holding transitional views both before and after the intervention. The major findings of this study are highlighted below:

- Pupils' views about the role of questions increased after the intervention, with more transitional responses observed. The VOSI-E survey includes a question that asks pupils how "scientists do their work" to evaluate this aspect. A pupil initially responded with a basic view in the pre-survey, stating, "Once they are finished with an experiment the scientists see what others had." In the post-survey, this pupil demonstrated an improved understanding by writing, "First, scientists ask a question, next the scientist research on their question, then the scientist make a hypothesis to help state their question, after that the scientist will experiment for an answer to their question."
- Pupils' views about experiments and investigations increased after the intervention as fewer pupils held naïve views, while the number with transitional and informed views increased.
- Pupils' views about developing scientific explanations increased after the intervention as the number of pupils with naïve views on this aspect of the scientific process decreased and the number of those with informed views increased. For instance, when pupils were

asked about the information scientists used to explain why dinosaurs died, a pupil initially presented a naïve view, stating, "They ask other scientists," but later provided a transformed view, stating, "They use data from what they got from the evidence."

- Pupils' views about supporting scientific explanations also increased as the number of pupils with transitional views increased. Similarly, the number of those with informed views increased significantly.
- After the intervention, pupils' perspectives about the role of subjectivity witnessed a change, with more pupils holding transitional views than naïve views as was before the intervention. For example, when asked if all scientists would come up with the same explanation for dinosaur extinction, one pupil initially answered "yes" due to it seeming logical but later responded that different scientists have various ways to find things, indicating a transitional view.

Discussion

Of the 46 primary 5 pupils in the study, most initially had a basic understanding of inquiry concepts, indicated by their scoring high at the naïve level. This may have resulted from limited instructional time in basic science and a focus on vocabulary-driven education. The curriculum to enhance learners' environmental knowledge for the preservation of the ecosystem, implemented for three weeks, helped address these issues by providing varied inquiry opportunities. This engagement improved some pupils' views of inquiry, showing that primary school pupils can grasp and develop inquiry knowledge when exposed to varied learning opportunities in formal and informal settings. Pupil engagement in activities situated in multiple contexts inside and outside the classroom setting provided pupils with opportunities to make connections between school and real-world science. This establishes the fact that informal settings add to pupils' classroom learning by providing experiential learning opportunities with authentic, real-world phenomena, as asserted by Looi et al. (2016), Zidny et al. (2020 and Erdyneeva et al. (2024). These authentic, real-world experiences position pupils to consider how science is conducted outside the classroom in ways that mirror the work of real scientists. However, these experiences become less useful when they are treated as stand-alone activities with minimal connection to what pupils are learning in the classroom (Zidny et al., 2020; Morag & Tal, 2012).

The integration of technology supported pupils in developing scientific questions and focusing the types of data they collected by providing limited observational categories. While some growth was identified in pupils' understanding of scientific inquiry, it was noted that this growth was minimal. This limited nature speaks to a weakness of the process and procedure for enhancing environmental knowledge through a combined use of technology. This points to the limitations in using technology to support pupils' understanding of how scientists do their work.

Conclusion and Recommendations

The research findings suggest that the pupils' understanding of scientific inquiry were 1) initially largely naïve and 2) difficult to shape, but 3) can be developed, even within a very short time, through a learning process that uses both formal and informal settings.

These findings also suggest that a curriculum structured around the use of technology and use of field-based inquiries that focuses on developing pupils' proficiencies in terms of generating and evaluating scientific knowledge and participating productively in scientific practices and discourse can play an important role in helping elementary pupils learn to do science. Achieving this is both the responsibility of curriculum planners, teacher educators and teachers themselves. In the context of these, it is recommended that:

1. Curriculum planners should emphasize the use of combined learning settings in science curricula, particularly at the primary school level, as this will help foster learners' acquisition of scientific process skills.
2. Effective use of these combined approaches in science teaching and learning will require well-prepared teachers. It is therefore recommended that teacher training institutions, both pre-service and in-service, expose teachers to ways to deploy this method effectively.
3. Integrating ICT in science teaching and learning will offer pupils the opportunity to engage in some science process skills, but this may have a limited impact. This implies that ICT should be combined with a combined approach that emphasises the effective utilisation of informal and formal settings in science teaching and learning.

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