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Prospective Primary Teachers' Challenges on Technology Mediated Learning in Science Classrooms

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ABSTRACT

Objective: *The study aims to investigate the students' use of technology in primary science classrooms. We employed research methods that drew on qualitative techniques such as survey instruments, students' completed assignments, and interviews.* ***Method:*** *The data analysis techniques were consistent with principles of theoretical sampling shared with the grounded theory approach to qualitative research. The data from survey instruments show that students perceive technology as things that help people and include both electronic and non-electronic things. Data collection over one semester involved 24 prospective primary teachers.* ***Results:*** *Fifteen themes emerge from students' completed assignments, and four major themes become evident, namely videos, experiments, models, and observation. Four major themes emerge from students' completed assignments: videos, experiments, models, and observation. The emerging data indicates that students perceive videos as technology that can facilitate observation and experiments of science by modeling (demonstrating) how the science practices work. The students' views on technology are not aligned with the nature of science.* ***Novelty****: This study supports the contribution of the social environment to the process of learning from others and from pre-existing culture. The findings identify that thinking and reasoning activities are mediated by cultural tools ranging from material artifacts to sign systems such as language and symbolic systems an aspect that has not been previously discussed.*

INTRODUCTION

This study investigates the pedagogical issues of prospective primary teachers (the third-year students) in using technology for science learning, particularly the role of technology in supporting primary school children's exploration of scientific ideas and in mediating their learning through social interactions with teachers and peers. Numerous research studies have examined the effects of technology usage on primary school children's science achievements and their understanding of science concepts (Hillmayr et al., 2020; Huang et al., 2020; Jawad et al., 2021; Liu et al., 2020). However, the quasi-experimental design of many of these studies is based on the assumption that higher test scores indicate better children's understanding of scientific concepts.

Less is known about how the availability of technology in science learning aligns with the nature of science (Bell & Clair, 2015). Some studies have found changes in classroom dynamics leading to a less teacher-centered and more exploratory environment (McComas et al., 2020; Russell & Maertin, 2023; Strat et al., 2024; Wang & Zheng, 2021). However, it appears that negotiation of such a pedagogical shift is mediated not only by teachers' mastery of the technology itself, but also by their personal philosophies of science and science education. Besides, the exploratory environment engages children only in the digital environment, instead of the natural environment.

While I believe that technology is a valid tool for science learning, it does present some significant problems. From teachers' perspectives, teachers today report increasing confidence using classroom technology to teach science. Although limited, they can operate software and search the internet. Given that technology is constantly changing, however, teachers need to stay up-to-date with their technological expertise. They often find this very challenging. Inadequate professional development and training to improve technological knowledge worsens this problem. Insufficiency in equipment, connectivity, and technological supports is also a major constraint (DeCoito, 2020; Sahin & Yilmaz, 2020; Walan, 2020; Wang & Zheng, 2021).

One of the main concerns from students' perspectives is the physical health effects, particularly those associated with digital technologies. Continuous usage of computers causes some physical disorders like eye strain, bad posture, and sleeplessness. When a person sits in front of a laptop or computer for a long time, there is a tendency for him or her to resort to snacking, exercise less, and even stay awake later at night. It states that "extended screen time is not only detrimental to health, but it can also result in eye fatigue and loss of concentration" (Pal & Patra, 2021). Unlike much previous research in this area, this study explicitly addresses technology as a tool that is integral to the science practice of students and teachers in particular learning environments.

This study examined whether the technologies developed by third-year students were aligned with the principles of the nature of science by identifying the themes that emerged from the students' technological creations and evaluating the extent to which these technologies reflected the characteristics and principles of the nature of science. The aim of the study is to investigate the students' use of technology in primary science classrooms. Science curriculum and policy documents now place increased emphasis on the processes of inquiry, reasoning, and communication, and endorse student discussion of science ideas as a means of developing and reflecting on their understanding of science concepts (the Next Generation Science Standards) (Ngss, 2013). These moves for curriculum reform are supported by current research in science education that draws on socio-cultural theories of learning (Guzzetti & Hynd, 2013). From this theoretical perspective, all human development involves learning from others and the culture that precedes us, and thinking and reasoning are mediated by cultural tools material artefacts or sign systems such as language, symbol systems, and so on.

RESEARCH METHOD

The study aims to investigate the students' use of technology in primary science classrooms. We employed research methods that drew on qualitative techniques such as interviews, survey instruments, and the collection of artifacts. In addition, individual cases such as a group of students who work on a specific task were selected and reinterviewed to gain a better understanding of the meanings the students ascribe to their ideas and artifacts. Since the aim is to derive theory from data inductively, the data analysis was consistent with principles of theoretical sampling shared with the grounded theory approach to qualitative research (Strat et al., 2024). The research workflow is illustrated in Figure 1 below.

Figure 1. Research design

Based on the research flow shown in Figure 1, this qualitative study uses a tangible, measurable sample. Data collection over one semester involved 24 prospective primary teachers (third-year students, referred to as students in this paper) from a single classroom. The students participating in this study were in the third year of the Primary Education program at Universitas Negeri Yogyakarta. Data collection spanned a full semester and involved interviews, surveys, artifact collection, and follow-up interviews with selected participants to deepen understanding. Data analysis employed *in vivo* coding to generate codes and group them into categories, ultimately identifying a core category through the processes of theoretical sampling and theoretical saturation. The final stage involved theory formulation and concluding, specifically inductively developing key themes to explain participants' behavioral patterns regarding technology use and to answer the research questions.

An essential procedure in doing qualitative analysis was coding. The initial type of coding conducted during the research project was in vivo coding, which derived directly from the language of the substantive field and the terms used by participants—the in vivo codes were analytical and imagery. Categories were developed from several workable codes, and the analysis was attempted to theoretically saturate as many categories as possible that seemed to have explanatory power. A category must be central, appear frequently in the data and codes, and be related easily to other categories. As the analysis consciously looked for a core variable or main theme when coding data, the generation of theory occurred around some core categories or major themes. The theory accounted for a pattern of behavior that is relevant to answer the research questions.

RESULTS AND DISCUSSION

Results

The students in this study supported the use of technology in their teaching, but fell short of assessing and building on science understanding within the concept of the nature of science. The data from students' completed assignments are shown in Table 1.

Table 1. Frequency from students' completed assignments

Major Themes	Frequency
Videos	78
Experiments	53
Observation	48
Model	42

The second result obtained is survey data showing that technology does not only refer to electronic devices. In the broadest sense, it refers to every object, system, or process that has been designed or modified to be useful to some person or group of people. Technologies are all things that people have designed and use for purposes. Few studies have assessed students' knowledge of technology, particularly among prospective primary teachers (Malone et al., 2018). While many students believe that technology only refers to things powered by electricity and have never thought about the objects they use as technology, students in this study perceive technology as all devices that allow them to teach science easily. This includes everyday objects, not only computers, electronics, or digital devices, but also non-digital and non-electronic tools, such as paper, whiteboard, or maps. The data from survey instruments are shown in Table 2. The mean score of 21 participants is 20 out of 21, with a maximum score of 21 and a minimum score of 12.

Table 2. Data from survey instruments

Instrument (Total Score)	Mean	Max Score	Min Score
What is Technology (21)	20.00	21	12

Data indicates that students perceive technology as anything created to assist and facilitate human activities in daily life. This understanding is not limited to electronic devices such as computers, smartphones, and televisions but also encompasses various non-electronic tools with practical functions, such as scissors, rulers, and vehicles. These findings demonstrate that students hold a broad concept of technology, viewing it as various forms of tools or innovations designed to meet human needs, regardless of whether or not they contain electronic components.

Discussion

Four major out of fifteen themes emerge from students' completed assignments, namely videos, experiments, models, and observation. These themes are in line with the students' interviews. Descriptions of each theme, illustrated with data from students' interviews and classroom observations, are offered in this section. The data indicates that students perceive videos as technology that can facilitate observation and experiments in science by modeling (demonstrating) how the science practices work. However, some videographic content presents science as facts and tends to be viewed by the students as absolute (Abed & Barzilai, 2023). The interview data also reveal that they accept the information straightforwardly without criticism. They also view the scientific content and models in the videos as reality and truth. These are distracting to the learners and constrain their learning. The students miss the opportunity to use technology to facilitate science learning and fail to maintain an understanding of the nature of science that scientific knowledge deals with uncertainty and is still tentative, evidence-based, as well as reviewed for accuracy and subject to critique (Covitt & Anderson, 2022; Park et al., 2026; Russel & Martin, 2023).

Students may be subservient to the technology if their knowledge, skills, and usage are limited to a narrow range of operations over which they have technical competence. In this case, subservience may become dependence if a lack of science conceptual understanding prevents them from providing the accuracy of the science concepts learned by the primary school children (Pal & Patra, 2021). The way in which video is perceived as technology for students becomes clear from observations when they complete one of the course's assignments. This student admitted very little knowledge of using technology in the classroom, to the extent that she regularly used YouTube to scavenge videos in order to demonstrate science concepts via the overhead projection panel. This student lacked personal autonomy in her use of technology, as she depended on videos to teach, although she planned to provide commentary and explanations to accompany the video display. Because of the syllabus and the course expectations, this student felt obliged to include technology-mediated learning activities in her lessons (Nikolopoulou, 2023). However, her own lack of knowledge and experience in using technology made her reluctant to use other technology to explore science concepts and activities. This gave rise to the statement.

1. I know very little about technology in science classroom, I think videos are technology that I will use as a means of delivering science theories or phenomena.
2. Other than videos, I'm not sure, we have so many technologies, like smart phones, and computer, but can we use those technology to teach science? How?
3. In my opinion, when compared to conventional learning methods where the teacher only lectures and does chalk and talk on the blackboard to make explanation about the topic, looks like teaching with videos and power points slides presentation already includes technology.

That may be very new to some students, so the learning is not boring, and students have a new way to learn. That helps us teach the content if we want technology, as a learning media tool, to be used in our classroom (W12FD). This response suggests that although the majority of the students are digital natives, they are still struggling to use technology in their science teaching. Almost all students have videos as part of their science teaching and have difficulty identifying other technologies they may use in their teaching. Videos contribute to more efficient learning by saving time and effort, especially in explaining natural phenomena and functional processes, as they provide clear visualizations of various science concepts and processes (Elme et al., 2022; Mallek et al., 2024; Tugun et al., 2020).

Here, technology is used for experimental activities, but the purposes of the experiments are for verification and confirmation of science concepts. That is, technology is a supplementary tool that amplifies hands-on scientific processes but is not used in creative ways or activities to explore the natural world and to enhance the minds-on science parts. This mode of experimentation is reflected in students' interview responses identifying advantages of using technology, such as the availability of many pieces of equipment resulting from developments in applied science; unfortunately, this use of technology is still not in harmony with processes that develop children's scientific skills and inquiry abilities. They commented that technology helped with laboratory and experimental activities, allowed them to justify scientific concepts more quickly and efficiently, reduced paper-and-pen activities, and was useful for checking answers on the worksheet. In subsequent responses, students acknowledged that there could be disadvantages to using technology if they lacked specific technological skills or if its use led to cognitive conflicts.

From the nature of science's perspective, technology is closely related to science, particularly if it simply supports students to understand what science is and how science works (Gericke et al., 2023; Lee & Zhai, 2024). Preferred teaching methods should be in line with this perspective, that the technology is used as a purposeful and explicit part of students' science learning, providing a medium for the students to demonstrate their investigation, creativity, and imagination in scientific works (Russell & Martin, 2023). Nevertheless, different versions in the way students operate with technology have been noted in this study. In this mode, one emergent property of the technology involves its use in establishing the truth, accuracy, or validity of science concepts. It is contended that these experiments, with technology used in conjunction with other material resources, can have consequences in ways that further enhance the myths and misconceptions about the nature of science. The position statement portrays the essential principles of scientific knowledge and concepts as still tentative yet reliable regarding the nature of science (McComas et al., 2020).

Here, technology is used derivatively to enhance the skills students exercise in observing natural objects and phenomena that human senses cannot perceive firsthand. For example, by providing access to scientific instruments or computer-generated digital information, students can observe microorganisms, genetic materials, or other "unobservable" objects and phenomena. It is asserted that science learning may involve using technology to facilitate observation or to explore different ways to understand science concepts (Sahin & Yilmaz, 2020). However, technology can reduce activities involving direct exploration of nature, as illustrated by the following student interview response:

1. Media can help you to understand things more easily, and facilitate understanding of science concepts without exploring the nature;
2. That is, I will use technology as a means of delivering science concepts, namely displaying powerpoints.

This comment suggests a degree of subservience corresponding to technology in the theme of observation. Students can observe natural objects and phenomena depicted in media rather than directly in nature. Furthermore, from the student's perspective, as a prospective primary teacher, teaching with media is always required to support learning. Integrating technology, which they referred to as media, may result in easier teaching practices, as they do not need to provide real objects in the classroom. In addition, they can manage the classroom better as they would have children sit still and observe objects and phenomena through images or videos.

An example of an image used in the learning process is an image of leaf structures. Instead of having children observe natural, real leaves, images (or digital images) are used in planned observation activities. With images and videos, the structures and functions of leaves are clearer, easier to notice, and better delivered, when compared to the real leaves. This mode of observation, however, does not improve students' observation skills, nor students' thinking and constructing science knowledge (Stieff & DeSutter, 2021). Another concern regarding the observation activities relates to how the technology is used. As students perceive that images are part of technology, children are told what they should learn, instead of providing opportunities for them to think about what to observe, to check their observation, and to discuss their thoughts.

This involves students incorporating technology as a part of their modeling and/or pedagogical skills in science learning. This is the most appropriate mode of functioning with technology, as students need intrinsically to know why technology is important to teach, and they need exposure to models for instruction, activities, and support systems extrinsically. Maintain that students use technology as modeling approaches to understanding science. The instructions included in-class observations of different types of scientific models, such as the model of the solar system, the water cycle model, or the models of environmental conditions.

Through a model, students can facilitate the development of very young children's thinking about a complex science concept, particularly models of processes in the world, which is a hallmark of the instructional approach using modeling, and support them in constructing their knowledge (McLaughlin et al., 2021). This is a way of developing a better understanding of science concepts. However, the skills needed to adopt the modeling approach are still underdeveloped. Instead of using technology as a model to help children think, teachers still teach science concepts to the children and have them listen to and observe the phenomena through technology.

One of the goals of science learning is for young children to explore objects and phenomena in the natural world through firsthand experience (Manz et al., 2020). Technology, including models as tools, has the potential to make learning easier for children in order to explore, observe, work with, and study the world "out there" (Hamilton et al., 2023; Walter, 2024). Modeling in science, as a focus in The Next Generation Science Standards (NGSS, 2013), is a defining characteristic of science, but is by no means an obvious system.

Modeling approaches using technology have both the potential and the challenges with students' science learning, including young children. In this study, the students were unfamiliar with employing these approaches, which is in line with science inquiry. The analysis revealed that although students encouraged the use of technology in learning scientific concepts, the instruction plans were generally teacher-directed. In this way, students tended to fall back on more traditionally authoritative modes of instruction, as opposed to those more progressively constructivist approaches of teaching that were aligned with the nature of science.

CONCLUSION

Fundamental Findings: This study identified four dominant themes in the technologies developed by third-year students for science teaching: videos, experiments, observation, and models. Although students demonstrated a broad understanding of technology, its implementation remained largely teacher-centered and was not fully aligned with the principles of the nature of science. **Implication:** Teacher education programs should strengthen the integration of technology with the nature of science by promoting inquiry-based, evidence-based, and student-centered learning experiences. **Limitation:** This study was limited to a small sample of third-year pre-service teachers and did not examine the implementation of the designed technologies in actual classroom practice. **Future Research:** Involve larger samples and investigate the effectiveness of instructional interventions that integrate technology with the principles of the nature of science in science teacher education.

AUTHOR CONTRIBUTIONS

Vinta A. Tiarani contributed to the conceptual framework, research design, methodology development, data collection, data analysis, interpretation of findings, and preparation of the original manuscript draft. The author was also responsible for literature review, validation of the research process, manuscript revision, and finalization of the article. The author has reviewed and approved the final version of this submission.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, as support in the research and writing stages of this article. Specifically, Grammarly was employed for correcting writing and grammar errors. All outputs generated with digital assistance were critically evaluated and revised to ensure academic rigor and ethical standards were upheld. The final responsibility for the manuscript rests entirely with the authors.

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