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Primary Preservice Science Teachers' Perceptions of Practical Work in Remote Learning Environments

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ABSTRACT
Science practical work is renowned for providing authentic environments for science learning in ways that reduce the abstractness of concepts. Significant resources are used to provide facilities such as laboratories to ensure that practical work is implemented in science learning. Practical work is important for primary preservice science teachers, who in turn will implement the instructional strategy in their future classrooms. The rise in remote learning has prompted researchers and instructors to reimagine ways of facilitating practical work in ways that involve human-machine interactions in significant ways. This study used an interpretive paradigm and an explorative single-case-study design to explore primary preservice science teachers' perceptions of conducting practical work in remote learning environments. A framework based on the Internet of Things- (IoT) enabled tools was used to mediate the understanding of the study findings. Data were collected from 25 preservice teachers by means of experiment reports and observation of practical work activities. The findings of the study showed that in the absence of proper systems for conducting practical work remotely and limited internet connectivity, the participating preservice teachers used internet searches to inform them of how to conduct experiments using household materials. The experiment reports comprised experiment demonstrations developed through the use of filmmaking applications, cloud computing tools, and social media collaborations. The paper makes recommendations to expand preservice teachers' technological competencies to include the use of virtual laboratories to conduct practical work in remote learning environments.

KEYWORDS
Practical work; preservice teachers; primary science; remote learning.

INTRODUCTION

Technological tools in the Fourth Industrial Revolution (4IR) significantly influence classroom practices, as instructors and curriculum designers reimagine learning facilitation. The Internet of Things (IoT) and Web of Things (WoT) have made available many technological tools that are at instructors' disposal to create an innovative learning environment. The IoT and WoT are used to create interactive environments between humans and machines (Ramlowat & Pattanyak, 2019). The interactions can be in the form human-human, human-machine, and machine-machine. Yousef et al. (2022) observed that the emergency remote learning during the COVID-19 pandemic further accelerated the evolving of learning environments as supported by the 4IR tools. These tools have enhanced the practice of distance learning (Dube & Ndaba, 2021).

This paper explores the implications of the increased use of remote learning for science practical work. The exploration is conducted in the context of reimagining how primary preservice science teachers engage in practical work in remote learning environments. The challenge of facilitating practical work remotely arises in the backdrop of other challenges that inhibit the implementation of the instructional strategy, such as lack of materials and equipment in science classrooms. Considering the challenges that inhibit practical work facilitation, Tsakeni (2020) proposed that preservice science teachers should learn how to improvise when they are faced with shortages of materials and equipment. Reimagining modes of instruction is consistent with the changing learning environments as prompted by the advanced technological tools of the 4IR and accelerated by the COVID-19 pandemic. During the COVID-19 pandemic, Mikeska et al. (2022) explored the use of simulated environments that enabled preservice teachers to practice how to teach in virtual classrooms with avatars in place of learners. The preservice teachers viewed the simulation tool as valuable in mitigating the challenges posed by the COVID-19 pandemic (De Klerk et al., 2021; Dube et al. 2022; Makura, 2022; Matarirano et al., 2021; Moyo et al., 2022; Nel et al., 2021).

Practical work is one of the instructional strategies inherent to science education. For many decades, practical work has been an inseparable component of science teaching and learning (Abrahams & Millar, 2008; Moore et al., 2020). The instructional strategy has several benefits that include helping learners to understand the nature of science and helping learners to develop science process skills, which include conducting investigations. In addition, practical work facilitates the use of other instructional strategies, such as inquiry-based learning, problem-based learning, experiential learning, project-based learning, experimentation, and field work (Woodley, 2009). Practical work is also used to develop cooperation, teamwork, communication, collaboration, and social skills in learners through instructional strategies that enhance learner-learner interactions. Practical work in science can be conducted through a variety of hands-on activities, such as experiments, laboratory work, investigations, field work, and projects (Kibirige & Maponya, 2021). Akuma and Callaghan (2019a) indicated that practical work can be computer-based in addition to other hands-on activities. The preceding discussion serves to support why practical work is considered central to science teaching.

Furthermore, science practical work is lauded for providing authentic learning environments where learners can handle materials and manipulate equipment, as compared to teacher-centered instructional strategies that make science concepts too abstract, thereby preventing effective learning. Some of the traditional methods of providing authentic environments include making learners work in prepared environments such as laboratories, classrooms, and beyond the classroom environment in which scientific phenomena can be observed and studied (Reid & Shah, 2007). In these cases, the learners are co-located with the instructors in real time. However, with the surge in distance modes of instruction such as remote learning enabled by the IoT and WoT, there is a need to understand how these technologies can be used in the context of science practical work. Similarly, Moore et al. (2020) wondered whether the facilitation of practical work in virtual learning environments can only be conducted by using teacher demonstrations, videos, and textbooks. The authors were quick to highlight that whilst these methods are useful, they should be complemented by more engaging activities such as purposeful discussions. Similarly, Tsakeni (2021a) showed that limited technological tool affordances lead to restricted ways of designing instructional strategies, which in turn lead to the use of asynchronous online classrooms. Related to this puzzle is how primary preservice science teachers perceive the conducting of practical work in remote learning environments. Accordingly, in this paper, the research question is: What are primary preservice science teachers' perceptions of conducting practical work in remote learning environments?

LITERATURE REVIEW

Computer-based technologies used to facilitate practical work remotely

Despite the centrality and the benefits of practical work in science education, its implementation in prepared environments such as laboratories and classrooms has always been met with challenges. One of the challenges is that practical work is resource intensive and schools find the cost too high to bear (Reid & Shah, 2007). Therefore, the facilitation of practical work becomes an access issue as some learners are denied this learning experience on the pretext of lack of resources (Tsakeni, 2018). In some instances, the use of virtual laboratories which offer a computational representation of reality is considered one of the ways to solve issues of lack of resources in school laboratories (Tibola et al., 2019). In addition, the virtual laboratories are lauded for mitigating the safety and environmental issues that are associated with real laboratories (Tibola et al., 2019).

In the immersive 3D virtual laboratories, learners can conduct experiments and manipulate variables. Ketelhut and Nelson (2010) showed that learners can learn equally in physical laboratories and in virtual laboratories. The immersive virtual laboratories can be used as a tool to facilitate practical work for learners in remote learning environments. Fan et al. (2021) indicated that virtual laboratories are web-based applications that can be easily accessed through devices that are available to learners, such as smartphones. However, in the African context, access to technologies such as computer-based simulation laboratories is still limited.

Akuma and Callaghan (2019b) classified the challenges hindering the implementation of practical work in South Africa and some other low-income parts of the world into three categories as macrosystem challenges. These are unsupportive curricula, material-related challenges, and non-material-related challenges, such as limited time. In creating remote learning environments using virtual laboratories, teachers must reimagine how to facilitate practical work in ways that reap the intended benefits of the instructional strategy.

Remote learning environments for practical work can also be created using remote laboratories. Remote laboratories consist of software and hardware tools that enable students to control equipment remotely and conduct practical work activities such as experiments (Orduña et al., 2015). Cooper (2005) deliberated on how students can conduct experiments in remote learning environments by exploring the use of remote laboratories. The deliberation by Cooper (2005) points to inhibiting challenges to the adoption and use of remote-controlled laboratories to include pedagogic, access, and usability issues. However, remote laboratories have been tried and used successfully in higher education. Some of the trials start with the development of internet-based remote laboratory systems by way of selecting and assembling the tools. Tho and Yeung (2016) explored the possibility of enabling remote experimentation for students in a science education program in Malaysia. An internet-based remote laboratory system was developed that enabled undergraduate students to observe and control laboratory equipment in addition to performing real-time experiments remotely. Whilst the participants confirmed that the infrastructure used to facilitate remote experimentation could be useful, they also identified areas of improvement, which the researchers used to enhance the remote laboratory system. The significance of the findings is that the infrastructure to facilitate remote experimentation should be improved regularly to enhance the pedagogical outcomes.

Researchers seem to find merit in the idea of remote experimentation in schools even at the primary level. Da Silva et al. (2014) piloted the use of remote experimentation enabled through the use of mobile devices, a learning management system (LMS), a remote experimentation application, and physics experiments. One of their notable findings is the importance of tools selection in ways that enable learners to engage in remote experimentation. In selecting the tools, instructors need to understand the interactions that are involved in the facilitation of practical work among humans and machines. Kong et al. (2009) showed that remote experimentation involves an interactive human-machine interface and that these technologies can be used with learners in schools. In the study by Kong et al. (2009), open-source software was developed that enabled students to learn by observing scientific phenomena in remote-controlled experiments. The emergence of remote learning brought about by the COVID-19 pandemic validated the usefulness of remote learning in many contexts, including schools. The findings of the study by Jan (2020) prompt instructors to think of ways to design remote learning effectively after highlighting the role of supervision by parents and the need to regulate the learner-machine interaction. As an identified challenge, the parents in the study by Jan (2020), however, considered the learner-machine interaction in terms of screentime to be excessive.

The challenges in adopting remote science laboratories in both higher education and schools mentioned by Cooper (2005) decades ago are still being experienced. One of the specific challenges highlighted by Sung et al. (2021) in the use of remote laboratories is the limited interaction among the learners and the instructors. Accordingly, in the study, Sung et al. (2021) developed a remote laboratory system that enabled teachers and learners to interact in real time by synchronizing the student-instructor-machine interactions. In their analysis, Sung et al. (2021) observed that the resultant interactions gave learners a form of telepresence that translated into enhanced learning gains.

The telepresence may be likened to the social presence component of the online learning framework of community of inquiry referred to by McKerlich et al. (2011), which affords learners a sense of participation. As remote laboratory systems are continually being designed, the identified adoption challenges can be considered in order to improve the systems. Using some of the identified challenges in the adoption of remote laboratories, Yousef et al. (2022) conceptualized basic design and development criteria for online laboratory work. The conceptualized basic design and development criteria for the online laboratory courseware system deals with content management, assessment, accessibility, usability, and adoption of artificial intelligence techniques. Both virtual and remote laboratory work are hands-on activities which can be conducted as learners are clicking on their devices through human-machine and human-human interactions.

Use of technologies to prepare preservice teachers

As remote learning is increasingly being applied, Reisoglu and Çebi (2020) observed that preservice teacher preparation needs to include the development of digital competencies in their training. Therefore, for preservice teachers to participate meaningfully in remote learning, there is a critical need to develop their digital literacies. In addition to developing problem-solving skills, the digital competencies include creating and sharing subject-related content and communicating and collaborating with others. Tsakeni (2021b) showed how preservice teachers used computational thinking with virtual laboratories as a strategy to engage in problem-solving when facilitating inquiry-based practical work for learners. The strategy enabled preservice teachers to identify possible learning challenges that hindered learning during inquiry-based practical work facilitation which were solved through computational thinking.

The use of innovative learning facilitation strategies mediated by the use of technologies is also being applied to the preparation of preservice teachers. One of the areas explored is the use of simulated teaching in which preservice teachers use 2D or 3D virtual immersive environments to practice learning facilitation skills. Calandra and Puvirajah (2014) used multi-user virtual environments with avatars (simulations of learner personas) for preservice teachers to practice learning facilitation skills. The virtual environments, as compared to real classrooms, have the advantage of allowing the learning preservice teacher to make mistakes without causing much damage to the development of learners. Similarly, Dalinger et al. (2020) explored the use of mixed reality simulations as a method to prepare preservice teachers for field experience. Simulations can provide authentic learning opportunities in a controlled environment with reduced risk of harm (Calandra & Puvirajah, 2014; Dalinger et al., 2020).

Developing teachers' digital competencies enhances their abilities to develop innovative instructional strategies (Tømte et al., 2015). The study by Tømte et al. (2015) showed that as teachers apply the digital competencies in teaching and learning, in essence, the learners also develop the digital competencies. Similarly, one of the take-away points from Wilson et al.'s (2020) study is the value in preparing preservice teachers for pedagogical uses of technologies to teach specific topics. This study explored primary preservice teachers' perceptions of conducting practical work activities in remote learning environments, which is a specific topic in science.

This study used some of the LMS IoT-enabled tools proposed by Mershad and Wakim (2018) as a conceptual framework to analyze the collected data and guide the understanding of the findings. The LMS tools that are enabled by the IoT are summarized in Table 1.

Table 1. *Learning management system IoT-enabled tools*

IoT-enabled tools	Examples of tools
LMS-enabled experimentation	Remote laboratories
LMS virtual reality experiences	Simulations and virtual trips
Facilitation of remote lectures	Synchronous and asynchronous online classrooms
Data sharing of real-life projects and experiments	Collaboration, communication, cooperation
Facilitation of student assessment	Online tests, submission of assignments, online presentations, and oral assessments
Student access to classroom applications	Digital textbooks, videos, discussion boards, wikis, texts
Improved security by granting secure access	The LMS is accessed by students who are enrolled in the course
Classroom monitoring	Monitoring for participation, attendance, and engaged learning

This study used the conceptual framework in Table 1 to show that a range of tools can be used to facilitate the learning of science practical work remotely. The framework provides expanded opportunities to design remote learning activities beyond the use of virtual and remote laboratories which are not readily available to all science classrooms. Moore et al. (2020) indicated that the facilitation of science practical work can be conducted by teacher demonstrations that are live-streamed or video-recorded, other videos that can be accessed online, and textbooks. Tsakeni (2022), after conducting a systematic review of literature, suggested five instructional strategies to facilitate practical work remotely in science, technology, engineering, and mathematics (STEM) disciplines. The five strategies are: (i) practical work in virtual reality environments, (ii) practical work in remote laboratories, (iii) practical work in augmented reality environments, (iv) the use of take-home do-it-yourself (DIY) practical work kits, and (v) the use of educational robotics to teach practical work. From Table 1, Mershad and Wakim (2018) seemed to emphasize the role played by LMSs in providing a learning environment in which instructors and students can readily and securely access applications and tools, be monitored, participate in assessment, and collaborate with others.

METHODS AND CONTEXT OF THE STUDY

The study was guided by the research question: What are primary preservice science teachers' perceptions of conducting practical work in remote learning environments? An explorative single-case study based on the interpretive paradigm of one natural sciences content course for primary preservice science teachers at one South African university was used. The natural sciences content course was facilitated remotely in 2021 during the emergence of remote learning brought about by the COVID-19 pandemic. One of the objectives of the course was to engage the preservice teachers in practical work activities that are facilitated for Grade 4 to 6 learners in schools. The course used student-centered instructional strategies that included the use of groupwork and collaboration to facilitate learning. In interpretive studies, the understanding of the findings is based on how they are constructed from the perspectives of the participants (Ponelis, 2015). Therefore, the primary preservice science teachers played a significant role as participants to provide data from which their perceptions were gleaned and interpreted. The use of the case study design enabled me to delimit the context of the real-life events that were under study and at the same time providing a holistic understanding of the meaningful characteristics of the participants' experiences (Kohlbacher, 2006).

The natural sciences course was facilitated in 2021 by me when remote learning was being implemented, triggered by the events of the COVID-19 pandemic. Learning was facilitated through the Blackboard LMS in conditions where internet connection was not reliable for preservice teachers due to electricity loadshedding and other access challenges. The intermittent internet connection resulted in the use of asynchronous online modes of instruction. Asynchronous online modes of instruction are a possible way to facilitate remote learning. DeNoyelles et al. (2014), however, cautioned that immediate feedback and discussion should be incorporated in the asynchronous online classrooms to enhance learning. Immediate feedback and discussions in remote learning conditions may be enabled by social media tools. Scott et al. (2016) and Saadatmand et al. (2017) noted a marked increase in the use of social media in teaching and learning and that it could complement the use of an LMS.

Participants of the study

The participants were 25 second year primary preservice science teachers purposely selected as they were enrolled in a course in which science practical work was facilitated remotely. The sample included 14 males and 11 females aged between 20 and 23 years who were in the second year of a Bachelor of Education (BEd) program specializing in primary natural sciences and technology and mathematics teaching for Grade 4 to 6. The 25 participants were organized into five groups consisting of five participants each.

Data collection instruments and procedures

Data were collected by means of document analysis and science practical work observation. To initiate the data collection process, the participants were requested to plan and conduct a practical work activity. They were further requested to demonstrate understanding of the steps of the scientific method by conducting an experiment of their choice from the Grade 4 to 6 South African natural sciences curriculum. The steps of the scientific method provided to the participants to use were: (i) formulating the investigative question, (ii) providing a background to the investigation problem, (iii) formulating hypotheses, (iv) making predictions, (v) conducting the experiments, (vi) presenting and analyzing the data, and (vii) drawing conclusions from the data. The participants were specifically tasked to submit the experiment report and to ensure that the researcher would be able to observe how they conducted the practical work activities. The participants were also requested to work in groups of five members and would therefore collaborate to complete the practical work activity. The communication between the researcher and the participants was facilitated through the Blackboard LMS. The practical work activity instruction was posted as an assessment activity so that a submission box would be available for the participants to post the completed activities, which were an experiment report and media that showed the actions of the participants whilst conducting the experiment. The submissions on the Blackboard LMS were, however, not taken as assessment activities. The participants were in different places and engaged in remote learning due to the COVID-19 pandemic. The participants themselves could choose the technological tools to complete the activity.

Data analysis

Data were analyzed through a combination of deductive and inductive qualitative content analysis. The data were deductively sorted based on the research question and the conceptual framework shown in Table 1. The data were further analyzed inductively to evaluate the strategies of remote practical work facilitation based on the participants' perceptions gleaned from the experiment reports and the observed experiments. Bingham and Witkowsky (2022) explained that deductive qualitative analysis is a process of sorting and organizing data into categories to maintain alignment with the research questions and the conceptual frameworks. Inductive qualitative analysis is described by Bingham and Witkowsky (2022) as the making of meaning out of the data, developing themes, and explaining the findings based on theories and reviewed literature.

Trustworthiness and ethical considerations

The trustworthiness of the data, through the measures of dependability and credibility of the findings, was ensured by using multiple participants (five groups consisting of five members each) to generate sufficient data from which the findings were drawn. The study was ethically cleared by the university and the participants' consent to participate in the study was sought.

FINDINGS OF THE STUDY

This section provides a description of the experiments conducted by the five groups of participants, followed by the discussion of the findings organized under four themes. Figures 1 to 5 show photographs of the experiments captured from the videos. Figure 1 shows that Group 1 conducted an experiment to investigate the water-holding capacity of different soils.

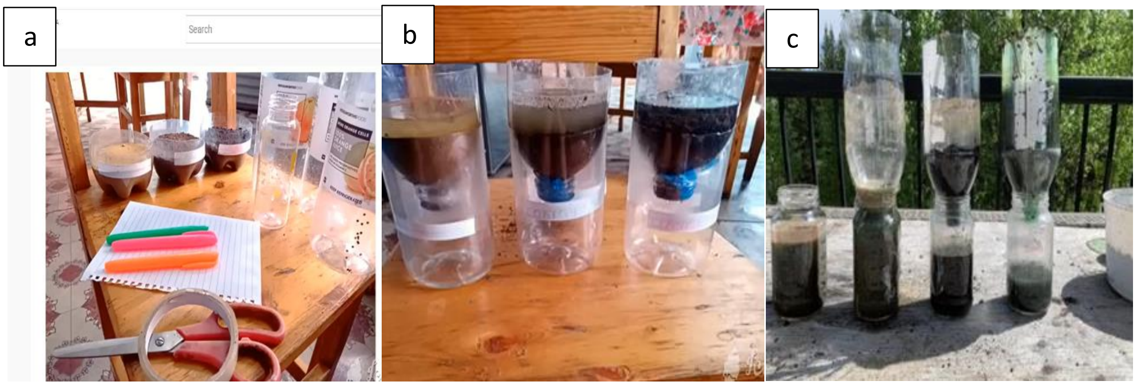

Figure 1. *Group 1 experiment: investigating the water-holding capacity of soils*

There is evidence that Group 1 conducted Google searches to select the experiment that they used. In the experiment report, the group included a screenshot (part c) that was taken of the experiment video searched on YouTube. Group 2 conducted a practical work activity to investigate how air flows between regions of high pressure and regions of low pressure using the egg-in-a-bottle experiment (Figure 2).

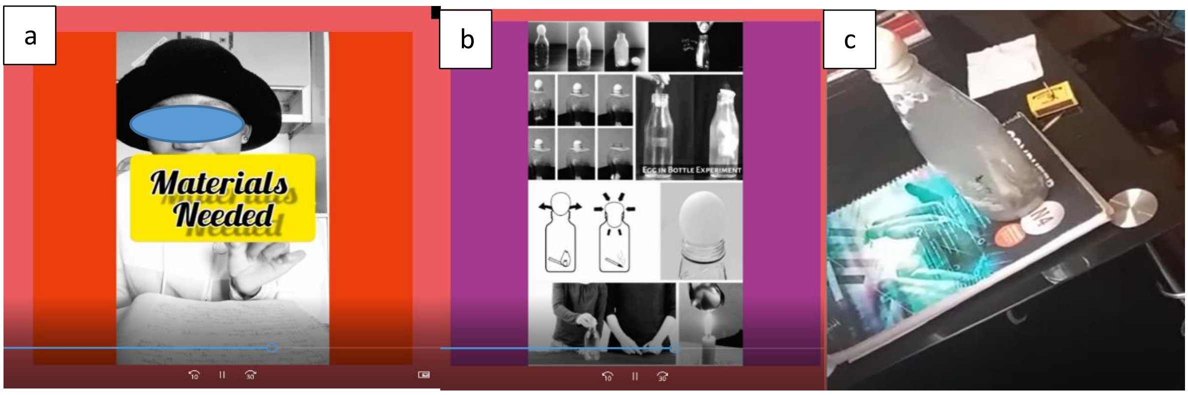

Figure 2. *Group 2 experiment: investigating the flow of air between regions of high and low pressure*

Like Group 1, there was evidence that Group 2 conducted Google searches to select a suitable experiment. Part b in Figure 2 shows a screenshot of the experiment video watched on YouTube. Group 2 used a filmmaking application to record and edit the video of the experiment they conducted. The filmmaking application was used to edit and combine two videos that were recorded in two different locations. The participant who conducted practical work in part a of Figure 2 is not the same one who provided the picture in part c.

Group 3 conducted an experiment to compare the densities of salty water and freshwater (Figure 3). The figure shows one of the participants conducting the experiment using household materials that included salt, drinking glasses and eggs.

Figure 3. *Group 3 experiment: comparing the densities of salty and fresh water*

Group 4 conducted an experiment to compare the time it took to bring frozen water and tap water of the same amounts to a boil (Figure 4). The purpose of the experiment was to show that more energy is needed for frozen water to reach a boiling point than what is needed for tap water.

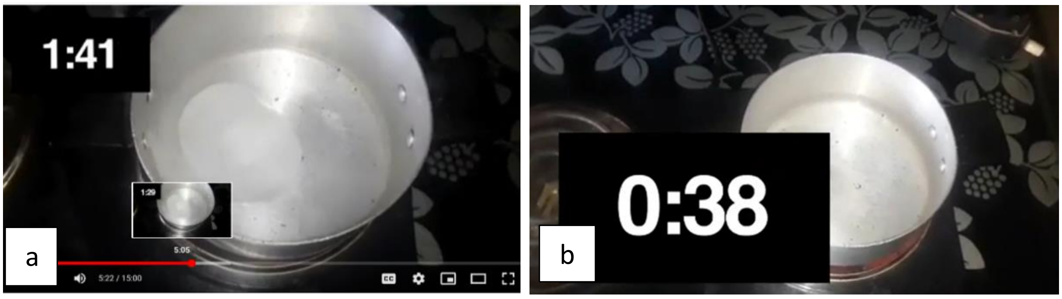

Figure 4. Group 4 experiment: comparing the time needed for frozen and tap water to boil

Group 5 conducted an experiment to show that sugary drinks may have a corroding effect on teeth by observing how eggshells dissolved in some selected drinks (Figure 5). All the participants of this group appear in the video, which means that the collaboration was partly facilitated by being co-located.

Figure 5. *Group 5 experiment: showing that sugar may have a corrosive effect on teeth*

The findings of the study are organized and discussed under four themes that emerged from the inductive qualitative data analysis. These themes are: (i) use of Google searches to identify experiments, (ii) use of household materials to conduct experiments, (iii) use of video recording and cloud computing technologies to manage content, and (iv) remote collaboration through social media.

Use of Google searches to identify experiments

Evidence showed that the participants conducted searches on the internet to select experiments that they could use to complete the activity. The experiments selected were found on YouTube. Groups 1 and 2 included screenshots of some of the videos that they had selected form YouTube. This finding seems to suggest that preservice teachers find YouTube videos useful as source of background information for experiments.

Use of household materials to conduct experiments

The participants selected experiments that allowed them to use materials that could be found in their households and locally. These materials included food stuffs such as eggs and soft drinks that were affordable and could be bought easily in local stores. It also included plastic containers that could be collected from the environment and could be found in their households. These participants were able to improvise in cases where the consulted YouTube videos suggested materials such as beakers, funnels, and filter paper, as shown in Figure 6. Part a of Figure 6 shows the recommended list of materials, whilst part b shows some of the improvisations.

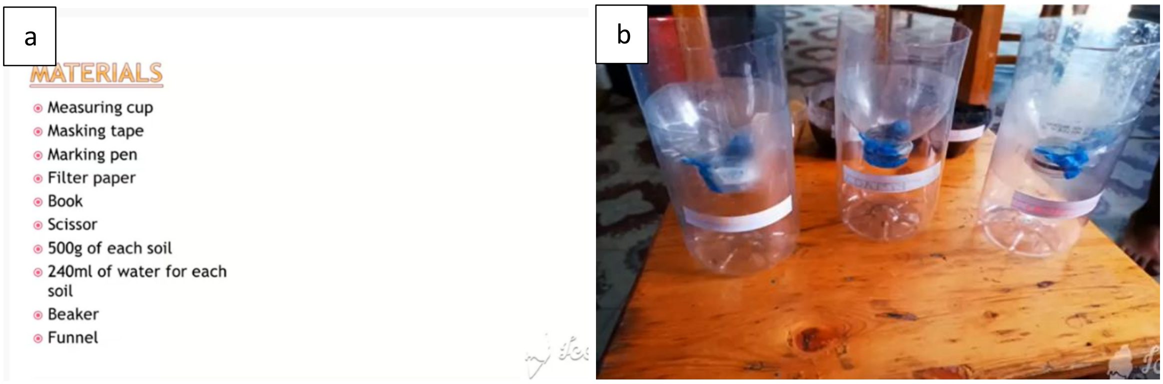

Figure 6. *(a) List of materials for Group 1’s experiment and (b) improvised materials*

Similarly, Group 2 used drinking glasses, whilst Group 4 used an electric stove from the kitchen in place of beakers and laboratory heaters and burners, respectively, as shown is Figure 4.

Use of video recording and cloud computing technologies to manage content

After selecting the experiments and gathering the materials that would be used to complete the practical work activities, some participants were tasked to record themselves whilst they were conducting the experiments. The recording of the videos responded to the part of the task that required the experiments to be observed by the researcher. The videos were recorded using filmmaking applications. The filmmaking applications enabled the participants to include other types of media, such as text and timers, in the videos. Group 2 used text to highlight the materials used in the experiment (Figure 2), whereas Group 4 used a timer to compare the time it takes for frozen water and tap water to reach boiling point (Figure 4). The participants used cloud computing technologies to save the videos of the experiments and file-sharing applications to submit the videos and the experiment reports on the LMS. Groups 1, 3, 4, and 5 uploaded the videos on YouTube and data-storage applications generating links that enabled easy sharing of the files.

Remote collaboration through social media

The LMS was used to facilitate the researcher-machine-content and preservice teacher-machine-content interactions and the asynchronous interaction between the researcher and participants. There was no facilitation for the participants to interact with each other on the LMS, partly due to the limited internet connection, which led to the use of asynchronous online learning. The limited-internet factor formed part of the study context. The collaboration among the group members was facilitated through the natural sciences course WhatsApp group. The group members further formed separate WhatsApp groups to communicate and collaborate to complete the task on practical work.

DISCUSSION

The study explored primary preservice science teachers' perceptions of conducting practical work in remote learning environments. The remote learning was facilitated by means of asynchronous online learning through the Blackboard LMS, with limited interaction among the participating preservice teachers and the researcher. Mershad and Wakim (2018) showed that remote learning can be facilitated through an LMS using media and applications such as text, audio, and video. However, DeNoyelles et al. (2014) highlighted that educational experiences in asynchronous online classrooms can be effective if strategies to enhance communication are incorporated. Similarly, Sung et al. (2021) indicated that limited interactions in remote laboratory work settings in turn limit the learning opportunities facilitated through collaboration and sense of participation. Theories such as community of inquiry highlight the importance of social interactions for effective learning in online classrooms (McKerlich et al., 2011).

For this study, the LMS was used for data collection by creating a submission box with the task to be completed and giving instructions to the participants through posting an announcement. In the practical work task used for data collection, the researcher requested to observe the participants, who were located in different areas, whilst they were conducting the practical work activities. The findings showed how the participants selected freely available technologies to communicate and to develop content.

The first finding was that through the affordances of the IoT, the participants conducted Google searches to find information on the experiments for the Grade 4 to 6 science classrooms. The remote practical work task given to the participants required them to not only consult the Grade 4 to 6 learner textbooks for the prescribed and recommended experiments, but they further had to find ways of being observed whilst conducting the practical work activities. Ramlowat and Pattanyak (2019) asserted that the IoT provides interactive learning environments among humans and things. In the case of the internet searches conducted by the participants, the IoT enabled them to access the content of the experiments through human-machine interactions.

The second finding was that the remote learning environment placed the participants away from the physical laboratories and classrooms where they could access materials and equipment to conduct the practical work activities. Therefore, access to materials and equipment to conduct the experiments was limited during remote learning. Akuma and Callaghan (2019a) indicated that practical work activities can be computer-based, although the access to the applications are still limited. As the participants had selected the experiments on YouTube, they targeted materials that could easily be replaced by household goods. The participants demonstrated improvisation skills by choosing experiments that used easily accessible materials. Household materials such as plastic containers, eggs, salt, drinks, soil and water were used. The plastic containers were redesigned and repurposed to be used as beakers and funnels. Tsakeni (2020) advocated for teacher preparation programs to equip preservice teachers with skills to improvise when the textbook-prescribed materials to conduct practical work are not available.

The third finding revolved around how the participants were able to select technologies that enabled the researcher to observe the experiments they conducted. Filmmaking and video-recording applications were used to capture the experiments that were conducted. The applications enabled the participants to edit the videos in ways that produced short presentations of 10 to 15 minutes. Four of the groups uploaded the videos on YouTube and the links to the recorded materials using uniform resource locators (URLs), which were included in the experiment reports submitted on Blackboard. The use of social media platforms (in this case, YouTube) for teaching and learning is increasingly becoming significant because it enables users to communicate and share content (Saadatmand et al., 2017; Scott et al., 2016). One of the groups used a filmmaking application to make a 10-minute-long video included in the submitted experiment report that was easily played by the researcher without connecting to the internet. There was evidence that the participants used cloud computing for data storage, which enabled them to submit the URLs for sharing the media files.

The fourth finding emphasized the collaborative nature of the practical work task. Except for one group, the participants were not co-located and communicated through the course WhatsApp group to form groups of five members as facilitated by the class representative. The participants used the WhatsApp platform as a means of communication and to engage in collaboration as they completed the task in remote learning environments. The communication and collaboration among the participants were, however, not facilitated through the LMS, which led to social media playing a significant role in their completion of tasks. Similarly, DeNoyelles et al. (2014) recommended that discussions should complement asynchronous instructional modes. Remote learning may result in limited interactions, as noticed and confirmed by Sung et al. (2021) for remote laboratory work environments.

The study findings show how the participants were able to select technologies used to support science practical work in remote learning environments. Tømte et al. (2015) underscored the need to develop preservice teachers' technological competencies that give them the capacity to develop innovative instructional strategies. Similarly, Wilson et al. (2020) called for the preparation of preservice teachers in technology competencies for topic-specific instructional strategies. In this study, the participants showed competencies to search for content that provided the background knowledge of the experiments to be conducted. Reading about the background of the investigative question of an experiment is one of the steps of the scientific method. The use of YouTube to develop the background knowledge and to determine how to conduct the experiments was a notable practice in this study. The science textbooks might contain information of prescribed experiments; however, they would not contain information on how to use the technologies to create and share media such as videos of experiments. The participants were able to select the technologies they used to complete the task given to them. This involved conducting experiments, ensuring that they were observed whilst conducting the experiments, and managing large media files that were part of the experiment reports to be submitted.

Although the literature (Sung et al., 2021; Yousef et al., 2022) has shown that the possibilities of facilitating practical work remotely are expanding due to IoT-enabled technologies, such as remote laboratories and virtual reality tools, these largely remain inaccessible in some contexts, such as in the case of this study. Although remote learning was facilitated through the Blackboard LMS, the tools in the LMS were not sufficient for the participants to complete the practical work activity tasks. The participants therefore used other IoT-enabled technologies that included search engines, YouTube, filmmaking applications, cloud computing, and social media platforms to complement the LMS affordances.

CONCLUSION

The emergency remote learning brought about by the COVID-19 pandemic has provided opportunities to implement innovative instructional strategies. The findings of this study showed that remote practical work was made possible through the incorporation of IoT-enabled tools such as search engines, viewing of YouTube videos to develop the knowledge to conduct experiments, and using of cloud computing and social media to enable communication, data sharing, and collaboration. Material improvisation and the use of household goods were very crucial in enabling the participants to engage in practical work activities, whereas internet searches and YouTube helped them to gain background knowledge on the experiments. The LMS could not be used effectively for real-time communication and collaboration due to the intermittent internet connections, which resulted in asynchronous online learning. Nonetheless, social media was used to enable real-time collaboration. Although the participants were able to conduct internet searches and use technologies to develop content, such as videos when conducting experiments, the use of virtual laboratories, which form part of the IoT- and WoT-enabled technologies, was not evident. The findings of the study point to a recommendation that the technological competencies of primary preservice science teachers should be developed to include the use virtual laboratories to conduct practical work in remote learning environments.

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