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The Pedagogical and Technological Experiences of Science Teachers in Using the Virtual Lab to Teach Science in Rural Secondary Schools in South Africa

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ABSTRACT

Effective science learning can be achieved when lab experiments become a central part of science curriculum. However, science learning in most rural schools is restrained by the deficiency of conventional lab equipment. From this viewpoint, it was imperative to explore alternative lab environments where learners can conduct the required experiments. This study investigated teachers' experiences in using the Virtual Lab to teach science. Particularly, this study is guided by the research question: What are science teachers' pedagogical and technological experiences in using the Virtual Lab to mediate science learning through scientific experiments? The findings are based on the individual teachers' and combined experiences on the use of Virtual Lab. Data were collected through semi-structured interviews, lesson observations, and journal reflections. The results reveal that the Virtual Lab has several benefits. It also indicated some shortcomings of the Virtual Lab. Nevertheless, the findings suggest the Virtual Lab is well-suited to be used as alternative to the conventional lab.

KEYWORDS

Information and Communication Technology (ICT), Pedagogical Experiences, Science Education, Scientific Experiments, Technological Experiences, Virtual Lab

INTRODUCTION

Science is a discipline of experimental evidence and inquiry where knowledge and comprehension of its concepts rely on the perception of natural phenomena. Among many researchers in science education, Lee and Sulaiman (2018), Aliyu and Talib (2019), Teig (2021), Lupp et al. (2021), and Destino et al. (2021) showed that resorting to laboratory experiments is one of the most effective ways to make understanding difficult and abstract concepts easier and clearer. According to Gyllenpalm et al. (2021), science learning can be effective when laboratory experiments become a central part of the science curriculum. This is because laboratory activities are the primary source of scientific knowledge, skills, and attitudes (Faour & Ayoubi, 2018; Makarova & Pavlicheva, 2021; Valls-Bautista et al., 2021). Gambari et al. (2017) asserted that learners learn better when they measure, touch, feel,

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manipulate, draw, record, interpret data, and make their own conclusions. In South Africa, like in many other developing countries, the curriculum and policy directs that learners must be able to plan and carry out investigations that require some practical ability in science subjects.

While real experimentation with conventional lab apparatus and equipment is greatly desired, most rural schools in South Africa, particularly in the Eastern Cape province, face limited resources, especially financial resources, to acquire and maintain lab equipment and infrastructure. Beck and Blumer (2021); Edwards et al. (2021), Mtsi and Maphosa (2016), and Tsakeni et al. (2019) reported that science learning has been restrained by the deficiency or inadequacy of laboratory equipment in most schools. From this viewpoint, it is imperative to explore new unconventional alternative laboratory environments where teachers and learners can conduct the required experiments while achieving the pedagogical objectives of science curricula. With the current advancement in the use of technology as the "new normal," a symbiotic relationship has emerged between the fields of science education and (information and communication technology) ICT in education. This has resulted in the proliferation of new technologies in teaching and learning. One of the novel technological advancements in the teaching and learning of science is the use of Virtual Lab (VL). VL is a simulated version of a traditional laboratory in which the learner is provided with instruments that are virtual representations of real objects used in traditional laboratories (Lestari & Supahar, 2020). This means that, with VL, the building and physical lab tools are transformed into software applications. Currently, free VLs are available for schools to use and do not need school Internet infrastructure.

With the aforementioned challenges faced by most rural schools, the authors conducted this interventionist study in which they sought to gain insights into the experiences of rural science teachers in making use of the VL technology to mediate learning of science practical experiments. This is important, because teachers' experiences in using educational technologies are often the key determinants for if and how they would integrate (or not) any technology tools in their pedagogic practices. This study, therefore, aims to illuminate and advance the new understanding of rural science teachers' experiences in teaching with the VL within the context of rural and resource-constrained secondary schools. Particularly, the study is guided by the research question: What are science teachers' pedagogical and technological experiences in using the VL to mediate science learning through scientific experiments? To foreground the response to the research question, the authors start the paper by reviewing the literature related to the topic, and then they present the conceptual framework that guides the study. The subsequent sections focus on research methodology, data collection, findings of the study, and discussion of the findings. Lastly, the authors end the paper by the conclusion and recommendations.

LEVERAGING THE USE OF CONVENTIONAL AND VIRTUAL LABORATORIES IN SCIENCE EDUCATION

Laboratory activities have important role in science learning (Sutarno et al., 2019). Laboratory activity in science teaching and learning is often referred to as a scientific experiment. Conducting scientific experiments in science learning is a cornerstone in developing learners' science problem-solving skills, which include formulating questions and hypotheses, carrying out experiments, measuring, reviewing what is already known in light of experimental evidence, using tools to gather, analyze, and interpret data, proposing answers, explanations and predictions, making conclusions, and communicating the results (Sutarno et al., 2019). These science processes are important because, according to Ateş and Eryılmaz (2011), learners learn better when they measure, touch, feel, make charts, manipulate, draw, record data, interpret data, and make their own conclusions.

Moreover, laboratory activities serve as a vehicle for constructing, reconstructing, verifying, and strengthening scientific knowledge (oghlu Sharifov, 2020). Proper scientific experiments can stimulate the development of low-order thinking skills to higher-order thinking skills, which allow students to function at the analysis, synthesis, and evaluation levels of Bloom's taxonomy (Pedaste et al., 2020). Scientific activities that can be used in students' learning process can be carried out in VLs (oghlu Sharifov, 2020).

A VL (VL) is a simulated version of the traditional laboratory that refers to a learner-centered approach, in which the learner is provided with instruments that are virtual representations of real objects used in conventional laboratories (Lestari & Supahar, 2020). Bogusevschi et al. (2020) defined VL as a highly interactive computer-based multimedia environment that brings learners into a virtual world that allows them to create and conduct simulated experiments, and to visualize in a 3D environment the effects of the experiment.

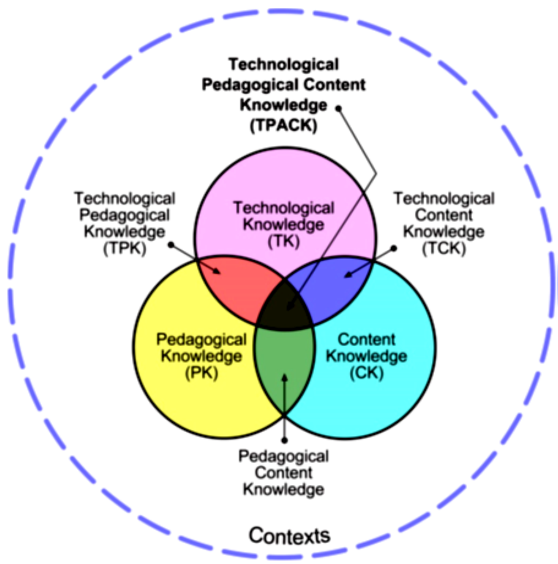
A VL contains a set of all apparatus such as microscopes, centrifuges, whole organisms or individual cells, each with specific preprogrammed behaviors (Aliyu & Talib, 2019). The learner can interact with the virtual objects in order to attain a set of given goals (i.e., the study of cell features, separation of cellular components, measurement of enzyme activities, and quantification of cell division) (Pedaste et al., 2020). The use of creative renderings of objects and their behaviors allows the learner to freely experiment in the virtual world. According to Aliyu and Talib (2019), learners can use graphics editor available in the framework to prepare lab reports after the exercises. Subramanian and Marsic (2001) pointed out that any stage of the lab can be captured and copied in the report document at the level of structured graphics, rather than screen bitmaps, and that the documents are stored in XML and can be reviewed and edited manually, if necessary.

In South Africa, the VL is still at a conception stage, and little relevant research emerged in the literature. The few studies available on virtual learning environments in South Africa are those conducted by Penn and Ramnarain (2019); Matome and Jantjies (2021), Penn and Umesh (2019); Ramnarain and Penn (2021), and Zhane'Solomon et al. (2018). Specifically, Zhane'Solomon et al. (2018) focused on university lecturers' perceptions of virtual reality as a science teaching and learning platform. In contrast, Penn and Ramnarain (2019) focussed on South African university students' attitudes and perceptions towards chemistry learning in a virtually simulated learning environment. In addition, Matome and Jantjies (2021) focused on student perceptions of virtual reality in higher education. All these studies were conducted in university contexts and none of the studies focused on secondary school teachers' experiences in teaching with the VL in rural and resource-constrained school contexts. Hence, research on VLs in South Africa in rural secondary school settings is very scarce. Therefore, a knowledge gap exists on rural science teachers' experiences in teaching with the VL in the secondary schooling settings. According to the researchers' literature review, this study was the first attempt to explore rural science teachers' experiences in teaching with the VL in resource-poor schools. Thus, the present study sought to bring to the fore new knowledge about the experiences of rural secondary school science teachers in teaching with the VL.

CONCEPTUAL FRAMEWORK

The work in this paper is grounded in the theoretical framework of technological, pedagogical, and content knowledge (TPACK). The TPACK framework, a build-up on Shulman's (1986) earlier work, has recently emerged as one of the most useful theoretical frameworks for thinking about the knowledge, skills, and dispositions a teacher needs to effectively integrate technologies into the classroom (Koehler & Mishra, 2009). Swenson et al. (2005) indicated that TPACK "involves asking how technology can support and expand effective teaching and learning within a discipline, while simultaneously adjusting to the changes in content and pedagogy that technology by its very nature brings about" (p. 222). TPACK theorises that effective technology integration into classroom practice should consider all three elements of content, pedagogy, and technology–not in isolation, but in complex and vibrant operational relationships that define teaching practice. The interaction of these elements of knowledge, both theoretically and in practice, produces the types of flexible knowledge that is needed to successfully integrate technology into teaching. It can be argued that knowledge of the different components of the TPACK framework does not necessarily mean the implementation of ICTs in teaching and learning. The implementation of technology in the classroom is multifaceted. Other factors (i.e., the availability of ICT infrastructure at schools and the learners' digital skills) affect the implementation of technology in the classroom. If all factors which affect ICT adoption and use are not addressed, then, implementing technology in teaching and learning might be impossible. Figure 1 and Table 1 show the resulting knowledge components of TPACK and their elaboration, respectively.

Figure 1. The TPACK framework with context



Source: http://www.tpack.org

Table 1. The seven constructs in the TPACK framework Chai et al., 2010)

The Constructs	Abbreviation	Definitions
Content Knowledge	CK	Knowledge of subject matter.
Technological Knowledge	TK	Knowledge of various technologies.
Pedagogical Knowledge	PK	Knowledge of the processes or methods of teaching.
Technological Content Knowledge	TCK	Knowledge of subject matter representation with technology.
Technological Pedagogical Knowledge	TPK	Knowledge of using technology to implement different teaching methods.
Pedagogical Content Knowledge	PCK	Knowledge of teaching methods for different types of subject matter.
Technological Pedagogical Content Knowledge	TPACK	Knowledge of using technology to implement teaching methods for different types of subject matter.

This study foregrounds the TPACK framework as the analytical lens to understand teachers' experiences in using the VL due to its alignment with the purpose of the study, and the possibility of the framework in helping to generate data to answer the research question of this study: What are science teachers' pedagogical and technological experiences in using the VL to mediate science learning through scientific experiments? The TPACK framework helped the authors to understand the connections and interactions between pedagogical knowledge (i.e., how to teach) and technological knowledge (i.e., how to do so with the use of technology, that is, the VL in this case), which are the areas that the authors sought to understand. In addition, the TPACK framework provides that knowledge and experiences about teaching with the technology are not context-free; therefore, the authors considered all contextual factors that could impact the teachers' experiences in teaching with the VL, such as school technology policies, availability of technology infrastructure as well as support from the school management teams.

RESEARCH METHODOLOGY

This study uses a qualitative case-study research design guided by the interpretive paradigm to gain an in-depth understanding of the teachers' experiences in teaching with the VL. As this study deals with exploring teachers' experiences on the phenomenon of using VL in teaching and learning, phenomenology offered the most relevant form of methodology (inquiry). This qualitative study is grounded on the precept that all experiences using VL and other technologies are based on an individual science teacher using technologies in teaching practices. Therefore, for the authors as researchers, the best way of accessing the teacher's lived experiences was to identify and try to forgo their perceptions and listen to the selected participants' meanings and experiences. Subsequently, the authors deemed the research approach of phenomenology that prioritizes the examination of conscious awareness through an investigation of the personal-technology relationship (Glasco, 2020; Simuja et al., 2016) most appropriate.

In order to capture the required experiences, the researchers (phenomenologists) had to recognise several assumptions that could inform the research. These include the assumptions that, in the study, teachers were to be viewed as active and intentional participants who are aware of their intentional use of technologies and who are capable of constructing experiences towards technologies used in their professional contexts, the choices that they make, and their ability to think and reflect on their practices. To understand the participants involved in the study, the authors were conscious of their contexts, situations, and experiences of being in the world as individuals or collectively with other teachers and learners (Webb & Welsh, 2019).

In general, the researchers were also guided by the belief that the participants (teachers) in the study are active agents in their teaching and lives, simultaneously reacting to and accepting technologies while seeking experiences. Subsequently, teachers, as any other persons, coconstitute meaning as they interact with an experience, and possibilities and the limitations of technologies. Therefore, the discussion, interpretation, and investigation of the phenomenon in the study is framed in the experiences of individual teachers. Only once the authors had examined this knowledge, the study shifted from the individual to the collective understanding of the nature of the unique experiences from the perspective of its lived qualities (Sacramento, 2019; Sonia, 2017).

In order to carry out the methodological processes, the researchers needed to negotiate a suite of qualitative methods, such as semistructured interviews, lesson observations and writing journal reflections. While the perspectives and the main intentions of the three methods were readily accessed and acknowledged for the type of knowledge being sought, the breadth of applications was less straightforward. For this interpretive and qualitative study, the researchers used purposive sampling (Gemiya, 2020) as a technique to sample the participants. The intention of purposively selecting participants in the study was to gain a deep and clear insight into the issues under investigation (Bakkalbasioglu, 2020; Etikan et al., 2016). The participants are secondary school science teachers from four rural schools in Amathole East District in South Africa; Table 2 below contains the participants' biographical data. The participants attended a three-day training workshop on using

VL to teach science. The researchers organized the training as part of their community engagement initiated by their affiliated university. In response, the researchers thought to take the opportunity of turning the initiative to research that could inform other teachers who are teaching in rural schools and in similar schooling contexts.

Table 2. Information about participants

Teacher (Pseudonym)	Age	Gender	Qualification	Number of Years Teaching Science in Rural Secondary School
T1	33	Male	BEd Agricultural Sciences & Life Sciences	9
T2	29	Male	BEd Mathematics & Life Sciences	5
T3	37	Female	BEd Agricultural Sciences & Life Sciences	13
T4	43	Male	BEd Honours degree in Educational Leadership and Management	19
T5	39	Female	BEd Agricultural Sciences & Life Sciences	14
T6	48	Male	BEd Life Sciences	24
T7	35	Female	BEd Agricultural Sciences & Life Sciences	11

The authors sought the ethics clearance from the Provincial Department of Education office and their affiliated university. The participants participated in the study voluntarily, and there was no coercion or deception. Participants were also allowed to withdraw at any point. Ethical protocols such as informed consent, confidentiality, anonymity, credibility, and trustworthiness were guaranteed during the conduct of this research.

DATA COLLECTION AND ANALYSIS

Prior to responding to participating in this study, all participants voluntarily signed the consent form and read the purpose of the study. The participants were also informed of their right to choose not to respond to any of the formulated questions. The data collection instruments were designed to capture data that could respond to the following question: What are science teachers' pedagogical and technological experiences in using the VL to mediate learning of science through scientific experiments? The researchers aimed to explore science teachers' pedagogical and technological experiences in using the VL to mediate learning of science through scientific experiments.

The aim was to collect data from 15 teacher participants. However, saturation was reached when data from seven participants was collected. Specifically, the researchers concluded that saturation was reached when data from participants eight, nine, and 10 did not provide any new information compared to the previous participants. Thus, they collected data from seven participants. All the teachers they selected to participate in the study responded to the interviews, writing a reflective journal and classroom observation. The researchers developed a set of open-ended and semistructured interview questions that would capture all the core themes for answering the research question. They e-mailed the questions to the participants prior to the interview. They conducted the interviews face to face with all COVID-19 pandemic protocols observed and audio recorded for transcription purposes. In order to mitigate the power imbalances and to build rapport and trust (Brinkmann & Kvale, 2015; Grinyer & Thomas, 2012), during the interviews, the interviewers gave the teachers (participants) authority and confidence by making them aware that the researchers were going to learn from their experiences before carrying out the interviews. In addition, the researchers arranged that the interviews would take place at a date and time convenient for both the participants and the researchers. They also gathered data through nonparticipant observation. This means that they were present in the classrooms, but not interacting or participating (Stake, 2010). In order to minimize the constraints that can be associated with observations, the researchers utilized carefully designed observation guides to capture all the pertinent issues for this study. Further, they scheduled the observation sessions in advance to ensure the participants' availability. The observation method was useful, as it allowed the researchers to gauge the participants' feelings about using the VL from their speech, gestures, and facial expressions.

The data analysis procedure included the researchers' use of a thematic analysis approach, which identifies, organizes, analyzes, and reports patterns/themes within data (Zammit, 2020). The researchers adopted distinct processes (e.g., transcription, organization, coding, analysis, and interpretation), which were not linear or systematic, but complex, iterative, and reflexive. For example, they started data interpretation and analysis during the interviews as suggestions of themes and possible codes began to emerge. They transcribed the recorded interviews using Microsoft Word software. Then, they analyzed the transcribed texts using NVivo, a version 22 data analysis tool. NVivo is a versatile, robust, and credible tool for collecting, organizing, and analyzing varied qualitative data types (Elliott-Mainwaring, 2021; Phillips & Lu, 2018). Subsequently they loaded each transcribed text onto NVivo and then analyzed it by grouping each participant's responses into categories or themes. They coded the participants' responses to the corresponding themes, so the coding process involved each relevant text to a relevant theme. Using an inductive approach of data analysis (MacMillan & Schumacher, 2006), the emerging pattern of themes became the source of the study findings.

FINDINGS OF THE STUDY

In this section, the authors present the findings of this study according to the teachers' pedagogical and technological experiences on the use of VL for teaching and learning science. The findings comprise science secondary school teachers' experiences, particularly. The researchers examined these experiences specifically considering the rise of ICT in education and the level of readiness or not of the teachers to adopt ICT. Moreover, the researchers consistently observed the tendency of teacher pseudonymity throughout the study to comply with the ethical requirements and ensure the participants' anonymity and confidentiality. They drew data for this study mainly drawn from the semistructured interviews and class observations. The data analysis gave rise to four themes (Table 3).

Table 3. Pedagogical and technological experiences in using Virtual Lab to mediate learning of scientific experiments

Theme	Description
1	Shortens the time required to teach experiments.
2	Availability of top-class lab equipment and up-to-date reagents.
3	Lack of hands-on approach.
4	Lack of direct supervision.

Virtual Lab Shortens the Time Required to Teach Experiments

Ntinda et al. (2021) conducted a study on the development and analysis of the VL as an assistive tool for teaching grade 8 physical science classes. They found that using the VL reduces the time required to teach science. As in Ntinda et al.'s (2021) research, in this study, one of the pedagogical experiences on which all the teachers agreed was that teaching with VL shortened the time required to teach the experiments. For example, one of the teacher participants, T3, stated in a journal:

What motivated me most about using the VL is that it makes more time available for the actual teaching. This is so because, unlike in the real lab, where my learners and I would need time to select the apparatus from cupboards where they are stored and set them up, and after the experiments clean and pack them, in a VL the equipment is readily available and needs no cleaning at the end of the experiment.

Similarly, T6 indicated in his journal reflections that teaching with aVL also allowed for experimental results to be realized soon. He stated:

I think, for me, what motivated me the most was, if I have to make my learners to see that light is necessary for photosynthesis, that would require my learners and I to use plants, and that would take several days or even weeks before we can observe the results. With the VL, we could speed up the experimental process and did not have to wait for weeks to see the results.

Although most teachers agreed that the VL shortens the time to teach experiments, T5 had a slightly divergent view, as follows:

I am excited that, with the VL, experiments that can take several days or conduct can be condensed and be done in a matter of minutes. My concern is that, although this technology makes the teaching of experiments shorter, does it really mean that learning these experiments is effective? On the part of my learners, what I noticed with the VL is mostly to do with excitement. I am not sure if there can be really a significant difference in performance between real Lab and VL, but, since we do not have a real lab, perhaps I should give the VL the benefit of the doubt.

These statements indicate that most teachers find the VL to be beneficial in their teaching of science experiments in terms of shortening the time required to teach the experiments. The shortening of the teaching time is an important factor, particularly in the context of heavy teaching workloads that teachers often experience.

Availability of Top-Class Lab Equipment, Tools, and Up-to-Date Reagents

Another factor in the use of a VL that the participants reported is the availability of top-class lab equipment and up-to-date reagents in the VL. T4 pointed out:

In my previous two schools, we had conventional science labs, but those labs, just like most rural schools, were equipped with outdated equipment and expired chemicals which often gave inconsistent and inaccurate results. That's when I realised that, in science experiments, modern instruments and up-to-date chemical reagents should be used and, in this regard, the VL is most ideal, as it is more likely to give reliable results with minimum chances of error and reporting incorrect results because of the modern apparatus that it uses.

In addition, T6 stated in the journal that:

Virtual experimentations have the benefit of reducing error because they use modern top-notch equipment. The modern instruments are very expensive, so most rural schools cannot afford them. The VL replaces the expensive real equipment with up-to-date simulated versions of the equipment.

These statements indicate that the teachers find the VL to be beneficial in their teaching of science experiments in terms of the availability of top-class laboratory equipment. This is particularly important in the context of the rural and resource-constrained schools, as teachers and learners from these schools could have access to up-to-date lab equipment. Rani and Dwandaru, (2019) reported similar findings, as they found that the VL can replace the real expensive equipment with up-to-date simulated versions of the real equipment.

Lack of "Hands-On" Approach

One of the pedagogical limitations of teaching with VL the teachers reflected and the researchers observed is the lack of a "hands-on" approach. Tobarra et al. (2020) reported similar findings. Teacher participants' comments illustrating this view were:

There are many benefits of the VL that I find important, but, in my view, there is an important missing dimension in the VL, and that is the lack of handling of the real equipment. What I know in science practicals is that learners learn better when they physically touch and manipulate lab equipment. These skills are important when conducting field experiments and yet they are not acquired through using VL. (T3)

In my opinion the whole aim of practical experiments is to make learners do science, and not observe science. The lack of physical interaction of learners with real apparatus makes me feel like the learners are just observing science experiments being done on their behalf by software. (T6)

A lot is not learnt, when using the VL to conduct experiments. For example, in a Life Sciences lab, much is learnt from slide preparation, namelyslicing, staining, and creating a microscope slide of a sample, calibrating and using a microscope, including drawing sketch-diagrams. All these important scientific skills are lost with the use of the VL. (T7)

Very useful to conduct virtual experiments, but I still think that the virtual activities should also be done physically, so the concepts are put into practice. The virtual experiments cannot equip learners sufficiently for real-life laboratory work. However, the VL is an amazing tool to provide laboratory simulation to the learners. (T4)

Despite the above comments, the researchers sustain that the VL could still be an effective alternative platform to conduct practical experiments, compared to the real Lab. This is because most of the rural schools do not have the traditional science lab. More importantly, in the context of the global COVID-19 pandemic, the researchers observed that the lack of a "hands-on" approach in the VL could benefit from stemming the spread of the coronavirus by not handling lab equipment that might be contaminated with the virus. Tobarra et al. (2020) supported this statement and pointed out that using virtual teaching and learning environments can help prevent the spread of coronavirus.

Lack of Direct Supervision of Learners in the Virtual Lab

One of the central characteristics of conducting science experiments is direct lab supervision of learners and facilitation by an experienced and more knowledgeable teacher. Some participants expressed concern that the use of the VL impedes direct supervision to the learners, which might lead to some learners failing to operate in the virtual environment. Oliveira et al. (2019) reported similar considerations. The following comments from T2's journal illustrate the concern of the teachers in this study:

Although I find teaching with VL advantageous in many respects, my concern is that we teach learners who are diverse in their cognitive abilities. For example, I found that mostly the self-motivated and mature learners could handle a virtual environment with little or no supervision and guidance. Since the VL is also useful to allow learners to conduct experiments even outside school, I do not think that most of my learners will be able to do that on their own. I picked that most of my learners really have difficult times understanding the language and the online learning skills. (T2)

When probed by the researcher to explain further about the online learning skills, T2 explained:

What I mean is that most of my learners come from poor backgrounds where it appears that they never had access to technological gadgets. In short, I would say they just lack technological skills to be able to learn online using technology.

Sharing the same view as T2, T4, in their journal reflections, indicated that:

Apart from the fact that I cannot directly supervise my learners who might struggle operating the VL in a manner that I would in a real lab, what I also find as a setback with the VL is the lack of a lab partner. A lab partner may facilitate peer-learning and, in the absence of such, an important learning tool is lost because peer-learning is also critical in the learning experience.

As the authors indicated earlier, another data collection method they used in this study was lesson observation. The researchers observed all seven participants and collected the observation data using a lesson observation tool they had designed. Their conclusive observation was that the teachers were able to give clear instructions and demonstrated to learners how to carry out the experiments using the VL. Thus, the teachers demonstrated and developed confidence in using the VL to teach.

DISCUSSION OF THE FINDINGS

When examining the pedagogical and technological experiences of science teachers in using VLs to mediate learning of scientific experiments, the findings from this study revealed both positive experiences and some disapproval from some teachers. First, most of the teachers indicated that the VL is an effective tool to teach experiments because it shortens the time required to teach and set the experiments. This observation is in the same direction as Ntinda et al.'s (2021) findings from their study on the development and analysis of the VL as an assistive tool for teaching grade 8 physical science classes. Indeed, these authors reported that the VL allows to speed up processes, thereby shortening the time to see the results. Aliyu and Talib (2019) reported similar findings in their study on a chemistry VL as a panacea to problems of conducting chemistry practicals at science secondary schools in Nigeria.

In addition, the availability of top-class lab equipment and up-to-date reagents is a feature that the teacher participants considered to be very important. As Destino et al. (2021) pointed out, the participants in this study appreciated the fact that, in science experiments, modern instruments, tools, and up-to-date chemical reagents are necessary as they are more likely to give reliable results with minimum chances of error and reporting incorrect results. Further, the participants evidenced that modern science lab instruments are very expensive and that most rural schools cannot afford them; as a result, many of the schools have outdated lab equipment and expired chemical reagents, which have greater chances of yielding inaccurate experimental results and affect the students experience of learning science.

As the authors indicated earlier, the teacher participants experienced that a pedagogical limitation of using a VL is a lack of a "hands-on" approach during VL experimentation. This supports the finding of Beck and Blumer (2021), who pointed out that, in a biology lab, for example, much is learnt from hands-on experience that the VL cannot offer, such as slide preparation (i.e., slicing, staining, and creating a microscope slide of a sample). Likewise, Vaez Ghaemi and Potvin (2021) indicated that learners learn better when they measure, touch, feel, make charts, manipulate, draw, record, interpret, and make their own conclusions. This, however, is inconsistent with Castelló et al.'s (2020) study on real and virtual biological science living laboratory for science teachers' training, in which they found that no statistical difference occurred between mean score marks of posttests of two groups of learners exposed to virtual and "hands-on" experimentation. The lack of "hands-on" experiences, therefore, may not be a pedagogical limitation, after all. In fact, in the context of the global COVID-19 pandemic, this study suggests that the lack of "hands-on" activities in a VL could indeed be a benefit in stemming the spread of the coronavirus by not handling lab equipment that might be contaminated.

Lastly, from the findings of this study, the researchers noted that some teachers expressed concern that there is a lack of direct supervision provided to the learners, which might lead to some learners failing to operate in the virtual environment. This concurs with previous findings of Bogusevschi et al. (2020), Monita and Ikhsan (2020), and Tobarra et al. (2020). It is noteworthy that, although the teacher participants raised the above concerns with the use of the VL to teach experiments, in general, they expressed approval for the use of the VL in rural schools' science teaching, when considering the benefits that they experienced in teaching with this tool.

FUTURE RESEARCH DIRECTIONS

Based on the findings from this study, the authors suggest a further in-depth study of factors that may inñuence the successful integration of the VL in the South African basic education sector. Such research should attempt to bring to the fore teachers' perspectives on the use of the VL for teaching and learning using a larger sample. The study can be further conducted on teachers of other districts as well as provincial or national level. The sample of the current study consists of the teacher participants working in different rural and underresourced schools, So future research might consider a sample made of learners. This study can be used to further examine the acceptance of the VL by the learners. In addition, the results of this study suggest that fully understanding teachers' pedagogical and technological experiences in using VL is paramount for ensuring the successful adoption of the VL for teaching and learning. Thus, in future research, it will be worthwhile to assess the possibilities of integrating the VL in South African rural schools in terms of the current infrastructure and ðnancial implications for the South African rural and resource-constrained schools.

CONCLUSION AND RECOMMENDATIONS

Several studies have underscored the beneðts associated with teaching with the VL. However, the literature review revealed that research on the integration of the VL as a teaching and learning tool in South Africa, particularly in rural and resource-constrained school contexts, is very scarce. This study contributes to the scanty literature on VL integration in South Africa, as it investigates the integration of the VL and opportunities and challenges associated with the VL as a teaching and learning platform from rural science teachers' perspectives in South Africa. In particular, this study contributes to understanding rural science teachers' experiences in teaching with the VL in resource-poor secondary schools. Available literature in South Africa highlights the potential use of the VL from university lecturers and students' perspectives, while hardly from secondary school teachers.

This paper presents teachers' pedagogical and technological experiences in using the VL to teach science through scientific experiments. The paper highlighted that the VL is particularly useful as it shortens the time required to conduct certain experiments. The teachers mentioned that certain experiments, such as investigating the effect of light on photosynthesis, would take several days or even weeks before the results can be observed. However, with the use of the VL, the teachers found that the experimental process could be speeded up. The teachers also believe that the VL provides them with top-class lab apparatus and tools that their resource-constrained school could otherwise not afford. In terms of the challenges, the teachers expressed their concerns about the lack of a "hands-on" approach in the VL, which, they believe, may lead to the loss of important laboratory skills needed in real life. Further, the teachers expressed concerns about the lack of direct supervision of learners in the VL, particularly for slower learners, who might need constant supervision by a more experienced lab partner or teacher. However, the results obtained in the present study demonstrated that the benefits of teaching with the VL far outweigh the challenges that are associated with the VL.

RESEARCH IMPLICATIONS

This study has theoretically contributed to the existing literature on the use of the VL and has helped to raise the question of the importance of teaching with the VL in South Africa. The study was the first attempt on the integration of the VL in the South African rural and underresourced secondary school context. Thus, the study will help rural science teachers in understanding the potential benefits and/or limitations of using the VL in their teaching. In addition, the study would be quite significant from a teachers professional development point of view. The Educational department can find out what support rural teachers need to effectively integrate the VL in their teaching, even with limited infrustracture resources at their disposal.

LIMITATIONS

This paper presents rural science teachers' pedagogical and technological experiences in using the VL to teach science through scientific experiments. Yet, the following limitations occurred: First, time constraints was one of the major impediments in this study; there was very limited time to conduct the study due to the schools' lockdown rules. Second, there was lack of proper Internet infrastructure in some of the research sites. The VL needed strong Internet connectivity to work and the poor Internet connectivity in some of the schools led to slow and suboptimal performance of the VL. Third, since the VL was a new platform and although a training workshop was conducted, teachers needed more time to first familiarize themselves with the platform, and this could not happen due to the limitation of time. Last, the findings of this case study are only applicable to the context of the cases studied and can not be generalised to a larger context. The study used seven participants, which might not have provided a wider view on the phenomenon of using the VL, even though the smaller sample was used to gain an indepth understanding of the teachers' experiences with the VL.

CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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