International Journal of Virtual and Personal Learning Environments
Volume 15 • Issue 1 • January-December 2025

Assessing Science Teachers' Acceptance of and Readiness for Virtual Lab in Rural Schools:

A Mixed-Methods Study

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ABSTRACT

In many Global South countries, including South Africa, the adoption of Virtual Lab (VL) remains largely conceptual. This paper emphasizes the necessity of understanding teachers' perceptions of VL before implementation to mitigate risks of abandonment or underutilization post deployment. Guided by the Technology Acceptance Model (Davis, 1989), the research employed a sequential explanatory mixed-methods approach. Phase 1 comprised a questionnaire survey with 186 randomly selected life science teachers in the Eastern Cape province, and Phase 2 involved in-depth semi-structured interviews with 4 teachers. Data analysis included descriptive statistics and thematic analysis. Findings reveal positive perceptions and a solid intention to adopt VL among teachers, highlighting its perceived usefulness in rural schools. However, caution is warranted as intention alone may not ensure actual adoption. This paper offers insights into the perceptions of teachers in rural regions, whose voices are conspicuously absent in the broader discourse on adopting novel technologies in science education.

KEYWORDS

Behavioral Intention, Perceived Ease of Use, Perceived Usefulness, Perceptions, Rural Schools, Virtual Lab

INTRODUCTION

Science education constitutes a ubiquitous element in secondary school curricula worldwide. Hodson (2014) outlined three primary learning objectives in science education: understanding science, understanding the nature and history of science, and developing scientific inquiry skills. The first objective involves comprehending scientific concepts, models, and theories. The second explores how scientific knowledge evolves. The third objective focuses on acquiring the skills necessary for scientific inquiry. Hodson (2020) later incorporated and continually emphasized a fourth learning goal, namely addressing socio-scientific issues. This involves developing critical skills to engage with the personal, social, economic, environmental, and moral-ethical dimensions of science. This paper specifically focuses on learning to do science, particularly in the context of 'laboratory work' in school settings.

DOI: 10.4018/IJVPLE.367602

Our work builds on Wellington and Ireson's (2017) three main arguments advocating for laboratory work in school science. First is the cognitive argument, which posits that laboratory work enhances learners' comprehension of science and fosters conceptual development. Second is the affective argument, which contends that laboratory work is motivating and exciting and generates interest in science education. The third is the skills argument, which asserts that laboratory work cultivates learners' practical and higher order thinking skills, including observation, prediction, and inference (Wellington & Ireson, 2017). Similarly, prominent science education scholars such as Schauble et al. (1995) and Hofstein (2017) have long contended that the school science laboratory is a unique resource that enhances learners' interest and knowledge of science concepts and procedures.

Despite the established wisdom on the centrality of laboratory work, a significant gap persists in advancing science education through laboratory work, especially in rural and under-resourced schools of the Global South. This gap is attributed to a myriad of challenges confronting rural school science education, including inadequate infrastructure, subpar service delivery, and insufficient funding (Assey & Babyegeya, 2022; Khethiwe, 2023). Consequently, despite persistent advocacy from UNESCO, governments, and numerous non-governmental organizations (NGOs) for quality science education for all, this aspiration remains elusive for most secondary school learners in rural and disadvantaged communities.

Faced with these restrictive conditions, many science education researchers (Larijani & Abedi, 2021) including historians such as Harari (2018), view educational technologies as a panacea to address present and future challenges in science education, including in disadvantaged and rural settings. Consequently, there is a growing call for teachers to incorporate technology into their teaching, driven by the perceived usefulness that technology offers, especially in science teaching. A notable technological development in the science education landscape is Virtual Lab (VL). Elfakki et al. (2023) defined VL as 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. In this paper, we view VL as a tool that enables learners and teachers to conduct experiments on digital devices such as computers and smartphones, converting buildings and physical laboratory instruments into computer software applications. Many VL programs are presently accessible and do not require school Internet infrastructure, providing a feasible option for schools.

Early adopters of VL report several benefits, including computer-simulated lab apparatus and non-expiring chemical reactants facilitating fully immersive and interactive virtual environments (Faour Abou & Ayoubi, 2017; Rossoni et al., 2024). Furthermore, VL proves advantageous in studying three-dimensional (3D) objects from diverse perspectives, even enabling the exploration of interior structures, such as atomic structures (Kapilan et al., 2021). A multitude of studies have demonstrated the positive impact of VL. Notably, Shambare and Simuja's (2022) literature review, encompassing 32 empirical studies conducted in 16 countries, revealed enhanced academic performance among learners exposed to VL. The reviewed studies span various countries, including Malaysia (Oloruntegbe & Alam, 2010), Slovenia (Herga et al., 2014), Italy (Pellas, 2014), the USA (Davenport et al., 2018), and Turkey (Kapici et al., 2022). Likewise, research in developing countries, such as studies by Aliyu and Talib (2019) in Nigeria, George and Kolobe (2014) in Lesotho, and Bhukuvhani et al. (2010) in Zimbabwe, has affirmed the effectiveness of VL in enhancing learners' academic achievement.

Although VL presents a groundbreaking approach to science education, its incorporation into classroom settings, notably in rural schools in the Global South, remains in its infancy. We assert that understanding the driving factors of teacher acceptance of VL could be a first step toward its successful adoption in rural school contexts. Researchers contend that teachers' perceptions are predictors of their behavior (Davis, 1989; Larijani & Abedi, 2021). Neglecting this exploration risks missed opportunities to utilize VL for rural science teaching. To realize our objective, we pursued the following research question: What are the perceptions of rural school life sciences teachers regarding the integration of Virtual Lab into classroom practice?

The key contribution of the paper includes unpacking VL perceptions from the viewpoints of science teachers in rural and marginalized regions, whose voices are conspicuously absent in the broader discourse on adopting novel technologies in science education. A notable innovation in this research lies in its focused exploration at the secondary school level, diverging from the prevailing emphasis on higher education in prior South African studies. This shift toward integrating VL for rural science teaching at the secondary level constitutes a pioneering research niche within South African science education. The paper is structured into sections, starting with a literature review providing essential context, followed by a discussion of the theoretical framework. This sets the stage for the methodology section, outlining the research approach. Results are then presented and analyzed, leading to a discussion of their implications. The paper concludes by acknowledging potential limitations, highlighting practical implications, and suggesting directions for future research.

LITERATURE REVIEW: SCIENCE TEACHERS' PERCEPTIONS OF VIRTUAL LAB

Various elements impact the incorporation of technology into science teaching, with scholars underscoring the crucial influence of teachers' perceptions on their decision-making processes (Davis, 1989; Granić, 2023). Ertmer's (2005) research is noteworthy, which revealed that teachers' internal barriers, predominantly stemming from their perceptions, significantly affected their adoption of technology. Specifically, science teachers have been observed to regard educational technologies as indispensable, demonstrating more favorable attitudes toward their integration (Carver & Todd, 2016; Larijani & Abedi, 2021). In this paper, we examine the subsequent investigations concerning teachers' perceptions and experiences of VL for teaching.

First, Larijani and Abedi's (2021) investigation into Tehran teachers revealed a crucial insight: Even in environments with limited technology access, positive attitudes toward technology are key to its successful integration. This finding aligns with the widely acknowledged idea that teachers' perceptions strongly influence their actions (Ertmer, 2005; Yazici & Nakıboğlu, 2024). Indeed, the significance of teachers' positive outlooks on technology cannot be overstated, as the acceptance or rejection of technology depends mainly on users' attitudes. Zeichner (2021) further emphasized this point, highlighting that teachers may possess the necessary technological skills but still hesitate to incorporate them into their teaching if they doubt their effectiveness. Hence, it is crucial to consider teachers' perceptions of technology before evaluating its actual implementation in educational settings.

Second, Oladipo's (2020) mixed-methods research in Nigeria delved into the perceptions and awareness of 1200 biology teachers regarding VL use for acquiring practical biology skills. Through questionnaires and interviews, data were gathered and analyzed using percentages and frequency counts. The findings unveiled a widespread lack of awareness among teachers regarding VL, with many demonstrating ignorance about its potential impact on acquiring practical biology skills. Consequently, the study advocated workshops aimed at equipping teachers with the necessary skills for utilizing VL in teaching.

Third, Hitlal's (2023) qualitative research in Trinidad and Tobago focused on the experiences of chemistry laboratory staff and learners participating in VL practicals. Through semi-structured interviews involving 34 participants, data were gathered and subjected to thematic analysis. The emerged themes encompassed various aspects, including the perceived significance of laboratories, challenges related to adapting to VL teaching and learning, insufficient training in using VL, lack of confidence, and participants' opinions and recommendations regarding the future use of VL.

Fourth, framed within TAM-3, Yazici and Nakıboğlu (2024) explored the perceptions of chemistry teachers and the factors influencing their use of VL in Turkey. Despite harboring positive perceptions, only a minority of teachers incorporated various VL functions into their teaching, indicating low usage rates. Reported challenges included technical issues, limited technological proficiency, Internet connectivity problems, and a dearth of suitable VL applications. This underscores the importance of acknowledging teachers' perceptions and the obstacles they encounter. Notably, our study distinguishes itself from Yazici and Nakıboğlu's (2024) research by focusing on rural and under-resourced schools in South Africa, whereas the latter was conducted in Turkey. Furthermore, this study adopted a mixed-method approach for a more comprehensive examination, setting it apart from the previous qualitative investigation.

Fifth, Caratachea and Monty Jones (2024) conducted mixed-methods research in Greece, examining the perspectives of in-service teachers (N = 41) regarding the adoption of virtual reality (VR). Data collection involved a questionnaire and an online debriefing. The study's findings indicate that VR holds promise in enhancing cognitive benefits and improving learning outcomes. However, the findings also underscore the need for instructional designers to address the challenges inherent in integrating VR into contexts beyond its intended use. As part of this endeavor, the study recommends implementing more systematic professional development initiatives to foster the creation of additional teacher-led interventions.

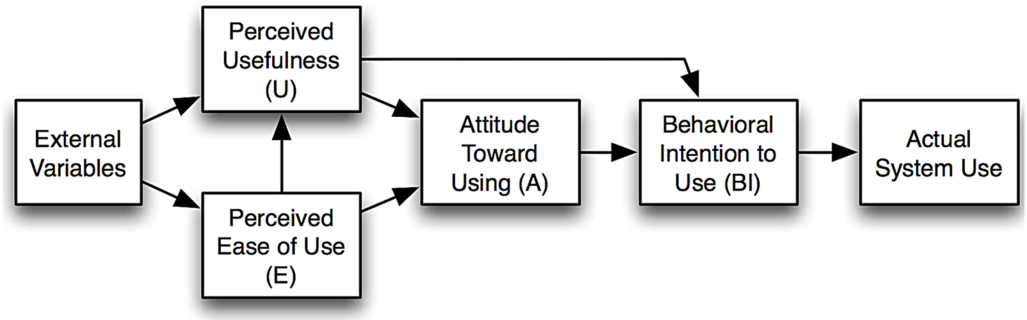
In South Africa, research on VL is notably scarce, with existing studies predominantly focusing on virtual teaching–learning platforms in university settings (Penn & Ramnarain, 2019; Ramnarain & Penn, 2021; Solomon et al., 2018). A notable contribution to this area is the study by Penn and Mavuru (2020), which examined the perceptions of 68 pre-service life sciences teachers toward VL experiments. Employing a sequential mixed-methods approach in a quasi-experimental design, the study revealed a positive and significant shift in pre-service teachers' perceptions toward VL experiments based on quantitative data analysis. Qualitative findings indicate that the integration of virtual experiments alongside traditional methods was beneficial for enhancing conceptual understandings, offering convenience, and promoting inquiry-based and self-directed learning. However, pre-service teachers noted that VL did not significantly develop their science process skills and could not entirely replace traditional laboratory experiences.

Building upon these prior investigations, our study aimed to address a critical knowledge gap by exploring science teachers' perceptions and experiences in incorporating VL as a teaching tool within secondary schools, particularly in rural areas.

THEORETICAL FRAMEWORK: TECHNOLOGY ACCEPTANCE MODEL

Davis (1989) formulated the Technology Acceptance Model (TAM), which focuses on perceptions, beliefs, and behavior related to technology acceptance. The TAM asserts that an individual's intention to adopt technologies is contingent on perceptions, specifically perceived ease of use (PEOU) and perceived usefulness (PU), identified as the two fundamental determinants of user acceptance (Davis, 1989). PEOU pertains to the belief that utilizing a particular technology would be uncomplicated or necessitate minimal effort, while PU involves the belief that using the technology will enhance work performance. According to the TAM, PEOU influences PU; therefore, if life sciences teachers perceive VL as "easy to use", they are likely to view it as "useful". The model delineates the interconnectedness of these constructs, including attitudes toward using (ATT), behavioral intention to use (BI), and actual use (AU). Favorable attitudes and perceptions of VL among life sciences teachers may lead to an intention to incorporate the technology into their teaching (see Figure 1).

Figure 1. TAM (Davis, 1989, p. 23)



Our research selection of the TAM was guided by its dominant position and robustness in investigating user perceptions of emerging technologies (Granić, 2023). Given the focus of our study on understanding life sciences teachers' perceptions of adopting VL in teaching, the emphasis of the TAM on teacher perceptions aligned seamlessly with our objectives. While acknowledging that the TAM has undergone modifications, such as TAM-2 and TAM-3, to address additional factors, we deliberately opted for the original TAM in our study. The decision to use TAM instead of its extensions, TAM2 or TAM3, is based on TAM's simplicity and parsimony. This aligns with the study's primary focus on PEOU and PU. TAM2 adds social influence processes, such as subjective norms, and cognitive instrumental processes, such as job relevance, output quality, and result demonstrability. TAM3 incorporates additional determinants, including individual differences, system characteristics, social influence, and facilitating conditions. However, these extensions increase the model's complexity. For studies where the primary aim is to understand the basic determinants of user acceptance without needing an in-depth analysis of various influencing factors, TAM''s straightforward approach can be considered more practical and effective. Therefore, we chose TAM to provide a focused and manageable framework, ensuring clearer insights into VL acceptance.

METHODS

Study Design

We employed a sequential explanatory mixed-methods design with two phases. Phase 1 involved quantitative data collection and analysis using a questionnaire. In Phase 2, we utilized semi-structured interviews for an in-depth exploration to gain the kind of knowledge we sought. The quantitative and qualitative data were 'mixed' during the results presentation and discussion stages.

Context of Study Sites and Participants

The research was conducted in South Africa's Joe Gqabi District in the Eastern Cape province. This district is predominantly rural, with most learners coming from households that rely on subsistence farming and government social grants as their main sources of income. Due to a scarcity of resources, most schools in the Joe Gqabi District are classified as quintile one, reflecting their rural setting and consequent lack of resources.

In South Africa, a quintile one ranking indicates a school serving children from the lowest 20% of households by income or expenditure (DBE, 2013). These households are typically located in rural and remote areas and face a high risk of poverty. This poverty is evident in rural schools, which often lack basic infrastructure such as classrooms, libraries, and science laboratories. As a result, schools with a quintile one designation are entitled to receive free or subsidised educational services.

Participants and Sampling Procedure: Phase 1

The quantitative phase encompassed 186 respondents drawn from a population of secondary school teachers in the Eastern Cape province (South Africa). To be included in the study, the respondents had to be qualified life sciences teachers teaching in rural and under-resourced schools and had to have access to technological tools such as computers at their workplace. Notably, all participants in the study were introduced to VL through technology integration workshops organized by the Eastern Cape Department of Education. Table 1 shows the demographics of the respondents.

Table 1. Demographic profile of the respondents (N = 186)

Gender	Male	Female				
n	67	119				
%	36	64				
Age (years)	> 21	22−30	31−40	41−50	51−60	61 <
n	7	48	64	51	13	3
%	4	26	34	27	7	2
Teaching experience (years)	0–4	5−10	11−15	16−20	21−25	26 <
n	30	68	39	32	6	11
%	16	37	21	17	3	6
Education level	Bachelor's degree		Post-graduate certificate	Master's degree	Doctoral degree	Other
n	97		65	11	0	13
%	52		35	6	0	7

The respondent profile highlights a gender disparity, with 64% female (n = 119) and 36% male respondents (n = 67). The majority of the respondents (61.8%) were distributed between the 31−40- and 41−50-year age groups. Furthermore, the largest segment (36.6%) reported 5−10 years of teaching experience, and a significant proportion (52.2%, n = 97) held a Bachelor of Education degree.

Participants and Sampling Procedure: Phase 2

The qualitative phase employed semi-structured interviews with four life sciences teachers from different schools. Participants were selected using a combination of convenience and purposive sampling methods. Convenience sampling considered factors such as geographical proximity and willingness to participate, while purposive sampling focused on individuals likely to provide insightful responses. Table 2 outlines the demographic characteristics of the interview participants, offering a snapshot of their backgrounds and experiences.

Table 2. Demographics of semi-structured interview participants

Name (pseudonym)	Age	Gender	Qualification	Teaching experience (years)
LST1	33	Female	Bachelor of Education (Life Sciences)	8
LST2	38	Male	Bachelor of Science, Post-Graduate Certificate in Education (Life Sciences & Natural Sciences)	14
LST3	49	Female	Bachelor of Education (Life Sciences & Agricultural Sciences)	23
LST4	28	Male	Bachelor of Education (Life Sciences & Mathematics)	5

Note: LST = life sciences teacher

Questionnaire Design

The study utilized a measurement scale adapted from Davis' (1989) classical scale, employing a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The questionnaire comprised two sections: The first collected demographic information, while the second gathered responses related to PU, PEOU, and BI. It is noteworthy that, except for minor wording adjustments tailored to the specific technology under investigation, no modifications were made to the user acceptance scale. The questionnaire used in the study consisted of 19 items, as detailed in Table 3.

Table 3. Number of items and sections in the questionnaire

Section	No. of items
Section A: Demographic information	7
Section B1: Perceived usefulness of Virtual Lab to teach science experiments	4
Section B2: Perceived ease of use of Virtual Lab to teach science experiments	4
Section B3: Behavioral intention to teach with Virtual Lab in the future	4

Internal Consistency and Reliability of the Questionnaire Instrument

We measured internal consistency using the Cronbach alpha coefficient (Cronbach, 1951). The figures we obtained, as shown in Table 4, demonstrate internal consistency.

Table 4. Questionnaire reliability statistics

Construct	No. of variables	Cronbach alpha coefficient	Result
PU	4	0.94	Very highly reliable
PEOU	4	0.90	Highly reliable
BI	4	0.86	Highly reliable
Total scale score	12	0.90	Highly reliable

Data Collection and Analysis: Phase 1

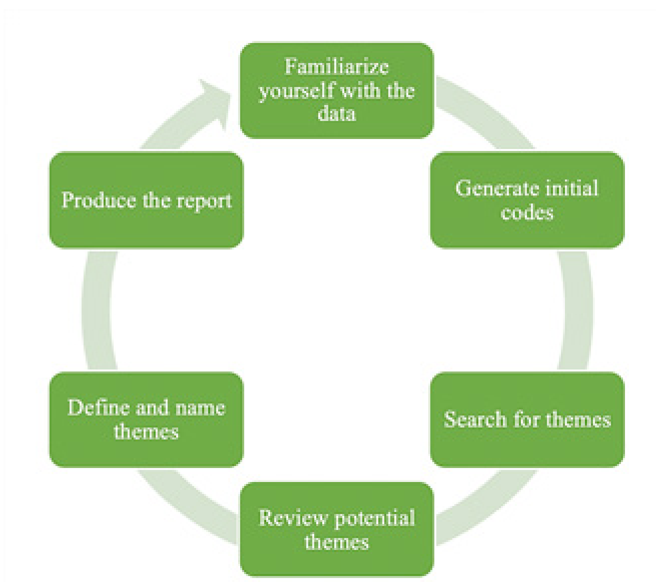
The questionnaire was randomly emailed to 200 life sciences teachers, allowing a 3-week response period. Upon receiving completed questionnaires, quantitative data were coded and captured on an Excel spreadsheet. Initial data cleaning identified 14 incomplete questionnaires, leaving 186 usable questionnaires for analysis. Data transferred to SPSS version 29 underwent descriptive statistical analysis focusing on standard deviations (SD), means (M), and frequencies (N) to examine teachers' perceptions of VL for rural school science teaching.

Data Collection and Analysis: Phase 2

In Phase 2, semi-structured interviews were conducted to augment insights from Phase 1 findings. Guided by the research objectives, the interview protocol facilitated the elicitation of detailed data. We scheduled the interviews at times and locations convenient for the participants. Each interview, conducted individually in English, lasted 30 to 45 minutes. This approach facilitated personalized and detailed responses in a private, focused setting. To ensure accuracy, we asked participants to review their responses. After an interview, we sent each participant a summary of the key points, inviting them to provide feedback, clarify any ambiguities, and make necessary corrections (member checking). We recorded and transcribed all interviews with the participants' verbal consent. Interviews, digitally recorded with permission, were transcribed and verified for accuracy. The transcribed data were uploaded to NVivo software for organization, utilizing tools for categorization and identification of themes and patterns.to dissect and analyze the data.

We adopted a thematic method to identify, categorize, analyze, and synthesize patterns or themes in the data (Braun & Clarke, 2006). This approach was complex, involving repeated cycles of reflection rather than following a simple, linear path. Our analysis and interpretation began during the semi-structured interviews as emerging themes started to take shape. The figure below presents the six-step thematic analysis framework proposed by Braun and Clarke (2006), which we followed in our analysis.

Figure 2. Thematic analysis framework (adapted from Braun & Clarke, 2006, 2012)



Although the six phases of analysis offer a structured progression, we often approached the process recursively, moving back and forth between these stages. After completing the six phases of the thematic analysis framework, we thoroughly analyzed each identified theme, crafting detailed narratives and evaluating their significance in relation to the research questions and the overall narrative of the data. We explored the themes in depth, identified any sub-themes, and examined how each theme connected to the research questions. We clearly defined and succinctly described each theme, assigning appropriate titles. Through data analysis, three prominent themes surfaced: Perceived usefulness of VL, Perceived ease of use of VL, and Behavioral intention to teach with VL.

Research Sites for Phase 2

All four participating schools, located in Mount Fletcher (renamed Tlokoeng in March 2022), constitute a rural setting within the Joe Gqabi district (Elundini Local Municipality). The rural community relies primarily on government social grants and subsistence farming. Reflective of the rural and under-resourced nature of the setting, all four schools fall under the Quintile 1 ranking. In South Africa, a Quintile 1 ranking denotes schools serving children from the bottom 20% of the country's poorest households.

Ethical Clearance

The study received ethical clearance from the General/Human Research Ethics Committee at the University of the Free State (approval number UFS-HSD2022/1276/22). The committee assessed the study to ensure compliance with ethical standards. Before participation, we provided detailed information to participants about the study's purpose, procedures, potential risks, and benefits to all participants. We hereby affirm that the research was conducted in strict accordance with ethical principles, prioritizing the rights and dignity of all participants throughout the study process.

RESULTS

To interpret the participating teachers' perceptions of VL, we employed Fisher and Marshall's (2009) classification to analyze the mean scores obtained from the 5-point Likert scale. Table 5 below displays the classification of mean scores.

Table 5. Classification of mean scores

Mean score	Classification
1.0−1.79	Very low
1.8−2.59	Low
2.6−3.39	Medium/Neutral
3.4−4.19	High
4.2−5.0	Very high

Teachers' Perceptions of Virtual Lab for Rural School Teaching

We examined teachers' perceptions of VL through the three components of TAM: PEOU, PU, and BI. Table 6 below presents the descriptive statistics of the TAM variables concerning life sciences teachers' perceptions of VL.

Table 6. Descriptive statistics for TAM constructs PEOU, PU, and BI

Construct	N	Mean	SD	Min	Max
PEOU	186	3.7581	0.7754	1.00	5.00
PU	186	3.8952	0.6476	2.00	5.00
BI	186	3.9651	0.5028	2.00	5.00

Table 6 indicates that life sciences teachers have a strong, positive view of VL, with high mean scores for all items exceeding the benchmark of M = 3.7 and low standard deviations (0.5028 to 0.7754), showing broad agreement. The BI variable stands out with the highest mean score (M = 3.9651) and the lowest standard deviation (SD = 0.5028), reflecting strong collective enthusiasm for adopting VL. Additionally, PU is rated higher (M = 3.8952, SD = 0.6476) compared to PEOU (M = 3.7581, SD = 0.7754), suggesting that teachers value the benefits of VL more than its ease of use.

Perceived Ease of Use

The questionnaire included four Likert scale statements on PEOU. Table 7 below presents the results for the statements.

Table 7. Descriptive statistics: PEOU (N =186)

Statement	Mean	SD	Min	Max
Learning how to teach with Virtual Laboratory is easy for me	3.677	0.9260	1.0	5.0
I find it easy to teach life sciences experiments in a virtual laboratory	3.817	0.9235	2.0	5.0
I find it easy to become skillful in teaching with Virtual Laboratory	3.801	0.9054	2.0	5.0
I find Virtual Laboratory easy to use	3.737	0.9475	1.0	5.0

Overall mean (3.7581), standard deviation (0.7754)

The analysis of PEOU statements shows that teachers view VL as user-friendly for rural teaching. The overall mean score for PEOU is favorable (M = 3.7581, SD = 0.7754), indicating that teachers find the learning curve manageable. Individual PEOU items, particularly the statement "learning to teach with Virtual Laboratory is easy" (M = 3.677, SD = 0.9260), also received positive feedback, though with some variability. Interviews with three out of four participants confirmed the ease of learning VL, highlighting the effectiveness of step-by-step instructions.

> *As a teacher, I appreciate the user-friendly nature of Virtual Lab, which has easy-to-follow instructions and demonstrations. It makes it easy for me to teach experiments like food tests, where chemicals are not readily available at my school. (LST1)*

LST1's perspective suggests a positive inclination among rural school life sciences teachers toward adopting VL for teaching. Survey analysis revealed that the statement "I find it easy to teach life sciences experiments with Virtual Laboratory" had the highest mean value (M = 3.817, SD = 0.9235). Despite response variations (SD = 0.9235), a significant majority of respondents perceived VL as user-friendly, anticipating it to enhance their teaching. Interview data further confirmed this trend:

> *Ours is a poor rural school deep in the rural area that lacks science equipment. But with Virtual Lab, teaching science can be a breeze. (LST4)*

Analyzing the interview responses underscores the multi-dimensional nature of the participants' perception of the ease of use of VL. The teachers believed VL to be user-friendly, which translated into facilitating their teaching in diverse ways. For instance, LST2 highlighted that VL enables the teaching of experiments that would otherwise be impossible due to the prohibitive costs of equipment and chemicals. His statement is illustrative:

> *My school is in a rural area with budget constraints, and physical science equipment is expensive. With Virtual Lab, all the equipment needed for experiments is available virtually, so my school does not need to buy any physical equipment. (LST2)*

Furthermore, he highlighted that VL could simplify teaching by virtue of its accessibility anywhere, anytime. Additionally, learners can repeat experiments as many times as needed to grasp the concepts:

> *My learners can perform experiments remotely from home, making teaching more flexible and accessible. This also allows learners to repeat experiments at their own pace and location, leading to a better understanding of the concepts taught. (LST2)*

Of note is the perception that the teachers “found Virtual Laboratory easy to use” (M = 3.737, SD = 0.9475), with a slightly lower mean score, but still indicating positive perceptions of ease of use. Additionally, the survey results showed that respondents found “it easy for them to become skillful in teaching with Virtual Laboratory” (M = 3.801, SD = 0.9054). While the majority of the life sciences teachers perceived VL as easy to use and that it facilitates their teaching, some interview participants expressed challenges with the technology. For instance, LST3 conveyed the following sentiment:

> *Navigating through the different experiments of Virtual Lab was difficult for me, and I had to spend some time figuring out how to use the software properly. (LST3)*

Overall, the descriptive statistics for PEOU revealed a mean score of 3.7581 (SD = 0.7754), making PEOU the third most influential construct shaping the life sciences teachers’ perceptions of VL for rural teaching. This indicates that the teachers perceived VL as user-friendly and easy to navigate. However, the SD value (0.7754) suggests some variability in the teachers’ perceptions, reflecting mixed perceptions of the PEOU items. This finding was not unexpected due to the newness of VL. Thus, while VL may be easy to use, some teachers felt they had limitations in terms of its optimal use. These limitations could be attributed largely to the unfamiliarity of VL among most teachers.

Perceived Usefulness

The survey respondents were requested to indicate their responses to four Likert scale statements for the PU of VL. Table 8 below shows the results.

Table 8. Descriptive statistics: PU (N = 186)

Statement	Mean	SD	Min	Max
Using Virtual Laboratory enables me to teach lab practicals more quickly	3.903	0.9072	1.0	5.0
Using Virtual Laboratory enhances the quality of my life sciences teaching	3.876	0.8766	2.0	5.0
Using Virtual Laboratory makes it easier to do my work	3.930	0.8256	1.0	5.0
I find Virtual Laboratory useful in my work as a life sciences teacher	3.871	0.8412	2.0	5.0

Overall mean (3.8952), standard deviation (0.6476)

Table 8 shows that the mean score for the PU of VL (M = 3.8952, SD = 0.6476) surpasses that for PEOU (M = 3.7581, SD = 0.7754). This suggests that the teachers, on average, valued the usefulness of VL more than its ease of use. The lower standard deviation for PU (SD = 0.6476) compared to PEOU (SD = 0.7754) indicates greater agreement among the teachers regarding the usefulness of VL in their teaching. Examining individual PU statements, respondents concurred that “using Virtual Laboratory makes it easier to do their work” (M = 3.930, SD = 0.8256) and “using

Virtual Laboratory enables them to teach lab practicals more quickly" (M = 3.903, SD = 0.9072). This aligns with the interview findings:

Virtual Labs can be time-saving since physical labs require setup time for the apparatus before conducting experiments and cleaning up and packing after experiments. (LST3)

Furthermore, analyzing respondents' responses to PU questionnaire items 2 and 4 reveals a consistent perception of VL as a platform that enhances the quality of life sciences teaching. The high mean scores for item 2, "Using Virtual Laboratory enhances the quality of my life sciences teaching" (M = 3.876, SD = 0.8766), and item 4, "I find Virtual Laboratory useful in my work as a life sciences teacher" (M = 3.871, SD = 0.8412), underscore the significance respondents attributed to the usefulness of VL. The extracted statements from interviews reinforce these findings:

Virtual Lab saves teachers time by eliminating the need for one-on-one assistance. As learners become more familiar with the program, it can provide instructions on its own, freeing up more time for assessment. (LST1)

While the primary focus of the interview questions was on VL usefulness in teaching, it is noteworthy that some participants also emphasized its advantages for learning purposes. This suggests that VL may positively impact not only the teaching process but also the overall learning experience for learners. LST1's statement below exemplifies this perspective:

Virtual Lab allows learners to repeat experiments as many times as needed to comprehend a particular concept, which is not always possible in physical labs due to limited resources. (LST1)

Additionally, the following comments indicate that participants perceived VL as beneficial in resource-constrained rural schools.

Given that we teach in Quintile 1 schools where we have limited funding to purchase adequate science teaching equipment, Virtual Lab proves invaluable as it offers a diverse range of opportunities for me to introduce my learners to practical experiments that would be otherwise impossible. (LST2)

To LST1, the PU of VL revolves around its capacity to facilitate learning anywhere and anytime. She articulated this viewpoint as follows:

Another point is that the experiences of the COVID-19 pandemic have taught us that there are times when teaching and learning may be impossible within school premises. In such cases, I see Virtual Lab as useful for learning anywhere, anytime. (LST1)

Conversely, LST4 specifically regarded VL as a secure platform for conducting experiments, as evidenced by the statement below:

I had a personal experience with an experiment that involved cutting an onion, and one of my learners accidentally cut themselves. This highlights a potential danger when conducting experiments in real-life settings. However, with Virtual Lab, such risks can be avoided altogether. (LST4)

Participant narratives highlight VL as a useful and secure environment for learner experiments. In the modern learning landscape, with smartphones and tablets, the flexibility of learning anywhere and anytime is crucial. Overall, respondents rated the PU of VL for rural teaching significantly (M = 3.8952, SD = 0.6476), second only to BI. Consistent positive perceptions, with minimal variation in PU responses (SD = 0.8256 to 0.9072), emphasize the efficiency gains and improved teaching practices associated with VL. The perceived ability of VL to expedite "teaching lab practicals more quickly" emerges as a crucial determinant for adoption.

Behavioral Intention

The respondents were requested to respond to four Likert scale statements for BI to adopt VL. Table 9 below shows the results.

Table 9. Descriptive statistics: BI (N = 186)

Statement	Mean	SD	Min	Max
I intend to use virtual laboratories more when teaching life sciences through experiments	3.871	0.6932	2.0	5.0
I would like to use Virtual Laboratory in all my experiments	3.935	0.7249	2.0	5.0
I would recommend using Virtual Laboratory to others	4.043	0.6883	2.0	5.0
I intend to use Virtual Laboratory more to enhance my life sciences teaching	4.011	0.6896	2.0	5.0

Overall mean (3.9651), standard deviation (0.5028)

Table 9 shows that among the three constructs, the respondents rated BI as the most significant, with an overall mean score of 3.9651 (SD = 0.5028). The high mean score indicates a strong intention to adopt VL in future lessons. The BI item "I intend to use Virtual Laboratory more to enhance my life sciences teaching" emerged as the most robust indicator, with the highest mean rating (M = 4.011, SD = 0.6896). Descriptive statistics and interview data both affirm a high agreement among participants in their intention to use VL in the future. The following interview comments highlight the teachers' intention to use VL.

I think I will use Virtual Lab going forward. You see, as a poor community, we need alternative ways of exposing our learners to those scientific experiments. Conducting experiments with our kids is a necessity. So far, Virtual Lab seems to be our only option. Besides, technology has come to stay, so we must embrace it. (LST3)

A particularly enthusiastic response regarding the intention to use VL came from LST1, expressed as follows:

I would say it is even late. Based on my experience with Virtual Lab, I feel it should have been here long ago. I say this because I see the limitless opportunities that Virtual Lab can offer in helping teachers to teach science more meaningfully. (LST1)

In addition to the perspectives shared by LST1, LST2 expressed the following sentiments:

By providing learners with access to a wider range of scientific experiences, Virtual Lab could inspire more learners to pursue science-related careers. (LST2)

The excerpts provided indicate a strong intention among the participating rural school life sciences teachers to adopt VL. Moreover, the analysis of BI items reveals a very high mean score for the statement "I would recommend using Virtual Laboratory to others" (M = 4.043, SD = 0.6883). To explore the extent of the participants' intention to use VL, a question was posed during the semi-structured interviews: "Based on your experience with VL, do you encourage all life sciences teachers to consider using it?" The subsequent participant narratives provide insights into their intention to encourage others to adopt VL:

I strongly encourage teachers, especially those working in resource-poor schools like mine, to adopt Virtual Lab. This will enable learners in these schools to conduct experiments and gain exposure to scientific concepts that may not have been otherwise accessible due to a lack of physical laboratory resources. (LST3)

The respondents consistently expressed a solid intention to adopt VL, which is evident in the high agreement for various BI items. Notable statements include, "I would like to use Virtual Laboratory in all my experiments" (M = 3.935, SD = 0.7249) and "I intend to use Virtual Laboratory more when teaching life sciences through experiments" (M = 3.871, SD = 0.6932). The prevailing sentiment is a shared belief among teachers that VL represents the future of science education in rural schools. Their relentless commitment to integrating VL into future classrooms reflects optimism about its potential advantages for enhancing the learning experiences of learners:

Yes, using a virtual lab would be awesome. It is great because they can learn a lot by doing things themselves rather than just reading about them in a book. That is how the world is going – more and more toward technology. (LST4)

The statements above indicate that the teachers' positive BI toward using VL can potentially influence the integration of the tool into their classroom. Consequently, the successful adoption of VL in rural school science teaching can be anticipated based on these findings. However, the investigation did not delve into whether teachers' positive behavioral intentions would translate into the actual use of VL in their teaching. This aspect remains a potential area for future research.

DISCUSSION

Perceived Usefulness of Virtual Lab

The research findings highlight that teachers view VL as a valuable tool for science education. They appreciate its time-saving benefits and its role in facilitating faster learning of science concepts. This supports previous research that VL helps streamline experiment setup and calibration, freeing up more time for teaching and learning (Engel et al., 2023; Faour Abou & Ayoubi, 2017). Teachers in resource-constrained schools, particularly in South Africa, see VL as a feasible and safe alternative for conducting experiments, reducing physical risks associated with traditional labs (Faralla et al., 2024; Kapilan et al., 2021). Additionally, VL's ability to offer anytime, anywhere access to experiments is valued, aligning with Caratachea and Monty Jones (2024), who noted its benefits for learners in remote areas. Overall, these findings indicate that life sciences teachers in rural schools perceive VL as crucial for enhancing their teaching. The PU of VL is a strong predictor of its adoption, suggesting that teachers are more likely to embrace it when they see its value for their work. This aligns with the views of other researchers (Hitlal, 2023; Yazici & Nakıboğlu, 2024) who emphasize that a positive perception of technology's usefulness is key to its acceptance. This study uniquely contributes by focusing on teachers in resource-limited settings, showing that they also recognize VL's value for teaching and learning.

Perceived Ease of Use of Virtual Lab

A significant finding indicates that the participating life sciences teachers perceived VL as user-friendly and intuitive for rural teaching, as reflected in the high mean score for PEOU. Insights from the semi-structured interviews corroborate these perceptions, emphasizing the provision by VL of step-by-step instructions, contributing to a straightforward learning experience. However, it is crucial to acknowledge that, despite the overall positive perception, a significant number of participants expressed challenges, suggesting that VL may not be equally easy to use for everyone. This finding is anticipated, given the novelty of the technology, and is a common occurrence in the initial stages of adopting any new technology.

Moreover, we can assert that teachers' intention to adopt VL in their future teaching is significantly linked to their perceptions of both its ease of use and usefulness. This connection arises from the preference among teachers for technologies that minimize effort while maximizing efficiency in teaching. Our findings highlight that a user-friendly VL holds substantial promise for seamless integration into rural schools, aligning with the views of Davis (1989) and Ertmer (2005). The research reinforces the significance of PU and PEOU as crucial predictors of teachers' intention to adopt VL, consistent with earlier studies by Penn and Mavuru (2020). Importantly, our paper delves into a relatively unexplored area in South African science education – the perspectives of teachers in rural schools on integrating VL. Focusing on this specific context provides novel insights into teachers' perceptions and experiences of VL in environments with limited science resources and infrastructure.

Behavioral Intention of Virtual Lab

Among the examined constructs of teacher perceptions (PU, PEOU, and BI), BI yielded the highest mean score, indicating a pronounced inclination among most participating teachers to integrate VL into future lessons. This robust intention challenges the perspective presented by Pyatt and Sims (2012) and Oladipo (2020) that abundant resources or urban school environments primarily drive technology adoption. Instead, this paper uncovered the agency, adaptability, and agility of the current teacher cohort in rural schools to leverage the potential of technology to overcome resource limitations and enhance science teaching. Despite working in resource-challenged environments, participants were enthusiastic about exploring and leveraging VL to improve their science teaching. This finding aligns with Zeichner's (2021) notion that teachers with a firm intention to integrate technology into their teaching are likely to incorporate it into their pedagogy. Moreover, the endorsement of VL by teachers suggests a positive trajectory for VL integration in rural schools, as this can also encourage colleagues to explore and adopt the technology.

However, despite the encouraging intent expressed, it is crucial to acknowledge, in line with Ajzen (1985) and Larijani and Abedi (2021), that intent alone may not guarantee widespread adoption and consistent usage of technology. While teachers seem open to embracing VL, the translation of intentions into actual practice is a complex process that may encounter challenges. These challenges could range from technological barriers and resource constraints to resistance to change, necessitating adequate training and support. Nevertheless, the solid intention of teachers to use and recommend VL, as indicated in this paper, sets a positive foundation for the successful adoption of this technology into rural school science teaching.

CONCLUSION

In the context of many Global South countries, including South Africa, VL remains mainly conceptual. We argue that it is essential to comprehend teachers' perceptions of this technology before actual implementation, as the absence of such understanding may lead to the risk of abandonment or underutilization post deployment in schools. This study delved into teachers' viewpoints on the integration of VL into rural school teaching, explicitly focusing on PEOU, PU, and BI. The findings indicate that the participating life sciences teachers in rural secondary schools harbored positive perceptions regarding the integration of VL for teaching. Notably, they overwhelmingly perceived VL as user-friendly and easy to use, emphasizing its potential for seamless integration into the rural school context. The prioritization of perceived benefits over ease of use underscores the perceived value of VL in enhancing science education in rural settings. Crucially, the teachers expressed a strong inclination and intention to incorporate VL into their future lessons. However, despite the promising inclination, a note of caution is sounded regarding the understanding that intention alone may not guarantee widespread adoption. Nevertheless, the positive perceptions suggest a transformative potential for VL in enhancing science education, particularly in resource-constrained rural secondary schools.

IMPLICATIONS

This paper pioneers research into VL adoption in South African rural schools, offering insights into teacher perceptions and informing targeted interventions to bridge the digital divide. These findings resonate globally, guiding discussions on integrating educational technology in marginalized regions. As technology evolves, this research contributes to refining virtual learning practices and enriching the ongoing dialogue on the role of technology in education worldwide.

LIMITATIONS

Every research study has inherent strengths and limitations, and the current study is no exception. This paper explored the perceptions of rural school science teachers regarding VL. The study faced constraints related to the data collection timeframe, which was conducted during a demanding period for teachers. This timeframe coincided with the pressure to cover the curriculum for year-end examinations, potentially impacting the thoroughness of the teachers' responses to questionnaires and interviews. Furthermore, the limited number of interviewees may not comprehensively represent the diverse experiences and perspectives necessary for a thorough analysis. This restricted sample size could affect the generalizability of the findings, as it may not capture the full range of potential variations in adopting VL. In addition, the study was conducted across a limited number of schools, which may also impact the generalizability of the results. The specific contexts of each school, including their unique administrative policies, technological infrastructure, and community engagement, likely influenced the ease or difficulty of adopting VL. Schools with more robust support systems and resources may have found the transition to VL smoother compared to those with fewer resources or less support. These contextual differences underscore the necessity of considering the individual school environments when interpreting the findings.

FUTURE STUDIES

This research anticipates the imminent widespread adoption of VL. With the expected roll-out in rural schools and similar contexts, the study recommends longitudinal, scalability, and sustainability investigations to assess the enduring effects of VL integration on teaching, learner engagement, and performance tracking over time. Given the evolution of technology adoption and teaching practices, conducting longitudinal studies spanning an extended period would yield valuable insights into the long-term impacts and challenges associated with VL integration in rural classrooms. These studies could focus on factors such as the cost-effectiveness and feasibility of VL integration in resource-poor rural schooling contexts.

CONFLICT OF INTEREST

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

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

PROCESSING DATES

This manuscript was initially received for consideration for the journal on 06/08/2024, revisions were received for the manuscript following the double-anonymized peer review on 08/17/2024, the manuscript was formally accepted on 09/13/2024, and the manuscript was finalized for publication on 01/02/2025

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