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Factors affecting the effective adoption of virtual laboratories in rural public secondary schools for science experiments

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Background: Virtual laboratories have emerged as a potential solution to the lack of physical laboratories for resource-constrained schools.

Aim: This study investigates the factors affecting effective adoption of virtual laboratories for conducting science experiments in rural public secondary schools in the Vhembe District, South Africa.

Setting: This study took place in rural public secondary schools in the Vhembe District, Limpopo province, South Africa, that lack physical laboratories for conducting experiments in science subjects.

Methods: To achieve the objective of this study, a quantitative approach was used. Therefore, data were collected through structured questionnaires and analysed using descriptive statistics. Furthermore, the IBM Statistical Package for the Social Sciences (SPSS) statistical tool was used to analyse data, and Microsoft (MS) Excel was also used to generate graphs.

Results: This study has identified a lack of awareness, a lack of digital devices, maintenance costs and training as factors that could affect the effective adoption of virtual laboratories in rural public secondary schools.

Conclusion: The Department of Basic Education and its stakeholders must prioritise awareness workshops to equip rural public-school teachers and learners with knowledge of virtual laboratories and their significance for conducting online science experiments, thereby enhancing their understanding.

Contribution: This study contributes to the body of knowledge by highlighting key factors likely to affect the adoption of virtual laboratories by teachers and learners from rural public secondary schools for conducting science subjects' experiments.

Keywords: virtual laboratories; technology integration; rural secondary schools; science education; educational technologies.

Introduction

Science subjects require hands-on experiments to better understand scientific concepts (Shambare & Jita 2025a, 2025b). Science subjects such as chemistry are complex and, without hands-on experiments, may affect learners' performance (Manyilizu 2025) due to a lack of experiments in schools. The Department of Basic Education report (2024) highlighted that the performance on science subjects is continuously dropping in rural public schools. Few scholars suggest that the low pass rate is linked with the lack of physical labs (Achuthan et al. 2020; Shambare & Jita 2025a).

Therefore, virtual laboratories (virtual labs) have emerged as a pragmatic solution to bridge the gap in the lack of physical labs in schools and ensure equitable delivery of science subjects' teaching and learning (Reyes et al. 2024). A study conducted by Shambare and Jita (2025c) shows that teachers view virtual labs as a suitable solution for rural secondary schools to conduct experiments. On the other hand, they indicated that teachers perceived its usefulness and ease of use as positive towards the adoption (Ngema & Motlhabane 2025; Shambare & Jita 2025c).

In rural secondary schools, teachers are encouraged to adopt virtual labs because they are user-friendly and beneficial to teaching and learning (Kolil & Achuthan 2023). Furthermore, Achuthan et al. (2020) reported that the benefits of virtual labs, such as cost-effectiveness,

scalability and the ability to conduct experiments anywhere, present an alternative solution for schools without physical labs. Similarly, the rapid growth in the use of online science laboratories during the coronavirus disease 2019 (COVID-19) pandemic demonstrates the effectiveness of adopting virtual labs in schools (Raman, Vinuesa & Nedungadi 2021).

Therefore, the literature highlights that there is low adoption of virtual labs in rural schools (Ngema & Motlhabane 2025; Shambare & Jita 2025a). In addition, a few scholars suggest that the high cost of digital infrastructure and internet connectivity negatively affects the adoption of virtual labs (Achuthan et al. 2020; Raman et al. 2021; Shambare & Jita 2025c). However, a few studies by Shambare and Jita (2024, 2025a, 2025c) explore rural public schools, but they focus on teachers. On the other hand, there is a study that explored the virtual labs focusing on Grade 10 learners from rural schools (Ngema & Motlhabane 2025). Looking at this, there is a lack of studies in the literature that explore the use of virtual labs, focusing on both teachers and learners. Furthermore, there is limited literature that explores the factors that affect the adoption of virtual labs in rural public schools, focusing on both teachers and learners. Therefore, this study empirically explores the factors that affect both teachers and learners to adopt virtual labs in rural public secondary schools.

Literature review: Diffusion of innovation theory

A virtual lab is a digital platform that runs on various environments to simulate laboratory work, empowering users to perform experiments online without physical chemicals or equipment (Kolil & Achuthan 2023; Shambare & Jita 2025b). Virtual labs are composed of multimedia elements that simulate chemical reactions in 3D, showing chemical mixtures and reactions online. Furthermore, virtual labs bridge the gap by providing both teachers and learners with experiential opportunities that pose no risk to physical or chemical equipment (Sellberg, Nazari & Solberg 2024). Moreover, it is cost-effective and flexible, as teachers and learners can conduct their experiments at any time that suits them (Kolil & Achuthan 2023; Sellberg et al. 2024).

The diffusion of educational technology, such as virtual labs, can best be explained using the Diffusion of Innovation (DOI) theory. This theory describes how innovations are adopted in society through the exchange of information between members of the social system in which an innovation takes place (Rogers 2003). With regard to the use of educational technology in schools, the introduction of virtual labs can be described as an innovation (Ngema & Motlhabane 2025). This theory is especially applicable in the current research, as it offers a systematic approach for assessing factors that affect the adoption of virtual labs in rural public secondary schools.

One of the main characteristics of the DOI theory is relative advantage, which is described as the degree to which an innovation is considered to be better than existing solutions (Rogers 2003). Globally, virtual labs may be considered as a potential solution to conduct experiments in fields like chemistry, engineering, food technology, science, education and medicine, just to name a few (Hassan, Devi & Ray 2022; Kolil & Achuthan 2023). In those fields, virtual labs offer several advantages by promoting inquiry-based learning and enabling users to deepen their knowledge through practical work. Therefore, this overcomes the limitation posed by the theoretical learning approach (Shambare & Jita 2025b). The literature suggests that integrating lab work into theoretical learning offers a wide range of benefits by bridging the gap between abstract knowledge and application, fostering students' understanding rather than memorisation (Ngema & Motlhabane 2025). It has also improved the accessibility and scalability of labs to conduct experiments or practical work by learners (Hassan et al. 2022; Kolil & Achuthan 2023; Sellberg et al. 2024).

Some benefits include improving conceptual understanding, as it allows teachers to demonstrate the end-to-end process to students (Shambare & Jita, 2025c). After class demos, the student can try at home to see if they get the same results (Reginald 2023; Shambare & Jita 2025a). Therefore, if they get different results, it will trigger students' critical thinking skills, which, at the same time, promote problem-solving abilities. Consequently, throughout the process, the student will also develop practical technical skills to perform lab work (Ojetunde 2025; Sellberg et al. 2024).

Therefore, the literature shows that the adoption of virtual laboratories in higher education institutions and private schools has increased recently. Other scholars suggest that this is driven by advances in educational technology, given its flexibility and inclusivity (Alderbashi 2022; Ojetunde 2025; Reginald 2023). Thus, schools are implementing virtual labs to support the teaching and learning of science subjects. However, in a few cases, schools are migrating away from physical laboratory experiments due to maintenance costs and the risks posed by chemicals and equipment (Radhamani et al. 2021; Shambare & Jita 2025a).

Even though adopting virtual labs in learning institutions offers benefits, there are also challenges that affect their adoption (Hassan et al. 2022; Mwansa, Ngandu & Mkwambi 2025). Some of the challenges include a lack of infrastructure, insufficient training and concerns about the adequacy of practical skills development (Mwansa et al., 2025). Nevertheless, the literature shows that with continued investment in digital infrastructure, internet connectivity, professional development and so on, virtual labs are becoming an integral component of modern science education in schools (Kolil & Achuthan 2023; Sellberg et al. 2024).

In the virtual labs research domain, the results show strong positive intentions to adopt virtual labs in schools (Raman et al. 2021; Reyes et al. 2024; Shambare & Jita 2025c). However, it is also argued that intention does not translate into actual implementation (Radhamani et al. 2021). In semi-urban schools, teachers demonstrated positive perceptions and

strong intentions to adopt virtual labs (Jaradat et al. 2021; Shambare & Jita 2025a). However, actual usage remained extremely low (Nzabahimana, Ndihokubwayo & Mugabo 2024), and it is also significantly under-utilised by life sciences teachers (Ward et al. 2025).

In addition, compatibility also emerges as another key characteristic in the adoption of innovations because it involves the degree to which an innovation is consistent with the established values, needs and experiences of users (Rogers 2003). The literature reveals that the effectiveness of the implementation of virtual labs depends on the extent to which the technology is compatible with current teaching and learning curricula, pedagogies and facilities at the school (Sellberg et al. 2024; Shambare & Jita 2025a). Thus, the level of complexity associated with technologies has been found to affect adoption because complex technologies tend not to be easily adopted (Rogers 2003; Shambare & Jita 2025a). Because most rural schools lack adequate computer skills among teachers and learners, they may not be able to fully exploit the potential of virtual labs effectively (Ngema & Motlhabane 2025; Shambare & Jita 2025a).

Lastly, trialability and observability emerge as two additional critical characteristics that facilitate adoption (Rogers 2003). Trialability implies that users should have an opportunity to test the innovation prior to adopting it, while observability denotes the extent to which an innovation's consequences are observable (Reginald 2023; Rogers 2003; Shambare & Jita 2025a). It has been noted that teacher and learner exposure to virtual laboratory technology through trials makes adoption easier (Hassan et al. 2022; Ngema & Motlhabane 2025; Shambare & Jita 2025b). Observing the success of other schools implementing the innovation, especially in terms of improvements in learner performance and motivation, also accelerates adoption (Shambare & Jita 2025b). All these characteristics provide a framework to understand the factors affecting the effective adoption of virtual laboratories in rural public secondary schools for science experiments.

Research methods and design

In this study, to guide researchers in understanding the phenomenon linked to the factors affecting the effective adoption of virtual labs in rural public secondary schools, a positivist paradigm was employed (Myers 2013; Saunders, Lewis & Thornhill 2019). However, scholars postulate that the research paradigm can assist in determining research approaches (Creswell 2009; Kothari 2004; Myers 2013).

The literature highlights that there are three commonly used research approaches, namely qualitative, quantitative and mixed-methods research approaches (Kothari, 2004; Myers, 2013). The qualitative research approach utilises non-statistical data to explore and comprehend human experience, perspective and opinions, just to name a few, through identifying themes (Creswell 2009). On the contrary, the quantitative research approach utilises statistical data to address the research gap linked to social and human problems associated with a group of people or institutions (Creswell 2009; Myers 2013). Therefore, this study adopted a quantitative research methodology to investigate the factors that affect the effective adoption of virtual labs for conducting science subject experiments in rural public secondary schools.

The context of this study was rural public secondary schools offering a science stream in the Vhembe District of Limpopo province, South Africa. Seven schools were purposively selected, and the actual participants, comprising teachers and learners, were selected through census sampling. Census sampling was used because some schools had fewer than 20 students who were taking science subjects. This was used to select all participants from all schools and to reduce bias in the participant selection process.

Therefore, the target sample size of this study was 212 participants. The sample size of this study comprised 18 teachers and 194 learners. To ensure the credibility of this study's results, a structured questionnaire was used to collect data. Before actual data collection, a pilot study was done. A questionnaire was reviewed by specialists in science education, scientists and academics to confirm content validity and to resolve any possible issues regarding ambiguity in the questionnaire items. The data gathered through the questionnaire were subjected to relevant statistical analysis, wherein descriptive statistics such as frequency counts and percentages were calculated. The reliability of the tool was measured using Cronbach's alpha, which indicated an acceptable degree of internal consistency.

To cater to participants who did not have a digital device, both a hard copy and a *Google Form* were used to collect data for this study. Hard copies were distributed to all participants who did not have a digital device. To those who had digital devices, a *Google Form* link was sent to their personal email or via WhatsApp. Therefore, for both groups (learners and teachers), the survey was carried out using the same questionnaire, with wording changes only where required to ensure that the questions applied to each group. After completion of the hard copy questionnaire, data were captured in Microsoft (MS) Excel and later combined with data collected using Google Forms. Thereafter, the MS Excel file was uploaded to Statistica for analysis. Consequently, of the 212 distributed questionnaires, only 189 were returned, and 23 of them were not returned.

All the returned questionnaires were usable and hence were considered for data analysis.

Ethical considerations

Before commencing with data collection, ethical clearance was sought from the University of Venda (UNIVEN).

Ethical clearance to conduct this study was obtained from University of Venda and Research Ethics Social Science Committee (No. FMCL/25/BIS/18/2411). Participants' consent was also sought, and personal data that would expose their identity were not collected to protect and maintain privacy and security in the study.

Results

Before starting data analysis, the researcher tested the reliability and validity of the data. In this research, the data were captured, coded and edited using MS Excel and imported into the IBM Statistical Package for the Social Sciences (SPSS) tool for further analysis. IBM SPSS version 30.0.0 was used for descriptive analysis. To generate graphs, MS Excel was also used.

Reliability analysis

Cronbach's alpha 'α' (Cronbach, 1951) was used to establish the construct reliability of the survey questionnaires. This study used the six-level rule of thumb to evaluate the construct internal consistency of the questionnaires in line with Cronbach's (1951): (1) excellent (for $\alpha \geq 0.90$ values), (2) good ($0.80 \leq \alpha < 0.90$), (3) acceptable ($0.70 \leq \alpha < 0.80$), (4) questionable ($0.60 \leq \alpha < 0.70$), (5) poor ($0.50 \leq \alpha < 0.60$) and (6) unacceptable (for $\alpha < 0.50$). In line with Hair et al. (2018), all Cronbach's alpha values above 0.70 demonstrate high reliability. Table 1 shows that the survey instruments achieved internal construct reliability in the good-to-excellent range, with $\alpha \geq 0.80$ across the four constructs, thus demonstrating high reliability.

Demography of the participants

A total of 189 usable questionnaires were coded and analysed using the IBM SPSS software package. In addition, the percentages were used in MS Excel to generate graphs for image quality. In this section, Table 2 presents demographic information. Therefore, demographic information presents results on the role, gender, age, teaching experience, internet access and technological skills. The results revealed that 177 (93.65%) of the respondents were learners, while 12 (6.35%) of the respondents were teachers.

The results from data analysis revealed that 107 (56.61%) were female, while 82 (43.39%) were male. Furthermore, data on the age of the participants were collected, and the majority of 177 (83.65%) respondents were between the ages of 17 years and 20 years, while a small proportion of 3 (1.59%) respondents were within the age group of 21 years – 30 years and 7 (3.70%) respondents were between the ages of 31 years and 40 years. In addition, 2 (1.06%) respondents were between 41 years and 50 years. Lastly, the results revealed that there were no respondents who were above the age of 50 years.

Looking at the teachers' experience in teaching science subjects, the results show a balanced distribution of experience. The results reveal that 2 (16.67%) teachers had 0–1 years of working experience, while 4 (33.33%) had 2 years – 3 years of working experience. However, one (8.33%) of the respondents had 4 years – 5 years of teaching experience. Lastly, the majority of 5 (41.67%) had over 6 years of teaching experience in teaching science subjects in rural public secondary schools.

Therefore, in this study, the researchers collected data on internet access. The results revealed that both 177 (93.65%) learners and 12 (6.35%) teachers, who equate to 100% of the respondents, had access to an internet connection. Lastly, regarding demographics, a question explored both teachers' and learners' digital technical skills. During data collection of this study, the results revealed that 21 (11.11%) respondents had poor digital technical skills, while 75 (39.68%) respondents had moderate digital technical skills. Again, 65 (34.39%) respondents had good digital technical skills, while 28 (14.81%) had excellent digital technical skills.

Awareness versus use of virtual labs

The results in Table 2 show that out of 12 teachers, only 5 (41.67%) were aware of virtual labs, and 7 (58.33%) were not aware of them. However, out of 177 learners, results show that 67 (37.85%) were aware of virtual labs and 122 (68.93%) were not. The results also show that all the teachers who were aware of virtual labs were also using them. Looking at

TABLE 1: Cronbach's alpha reliability findings.

Constructs	Number of items	Cronbach's alpha (α)	Comment (based on Hair et al. (2018)
Awareness of virtual labs	5	0.897	High reliability
Adoption of virtual labs	5	0.908	High reliability
Virtual lab maintenance cost	5	0.855	High reliability
Virtual lab training	5	0.877	High reliability

Note: Please see the full reference list of this article, Ndou, P.T., Munyoka, W. & Mashau, N.L., 2026, 'Factors affecting the effective adoption of virtual laboratories in rural public secondary schools for science experiments', *African Journal of Teacher Education and Development* 5(1), a225. https://doi.org/10.4102/ajoted.v5i1.225 for more information.

TABLE 2: Demographic information.

Measure	Item	Frequency	%
Role	Teacher	12	6.35
	Learner	177	93.65
Gender	Male	82	43.39
	Female	107	56.61
Age (years)	17–20	177	93.65
	21–30	3	1.59
	31–40	7	3.70
	41–50	2	1.06
	≥ 51	0	0.00
Teaching experience (years)	0–1	2	16.67
	2–3	4	33.33
	4–5	1	8.33
	≥ 6	5	41.67
Internet access	Yes	189	100.00
	No	0	0.00
Technological skills	Poor	21	11.11
	Moderate	75	39.68
	Good	65	34.39
	Excellent	28	14.81

TABLE 3: Awareness and use of virtual labs.

Measure	Item	Teacher	Learners	Total	
				Frequency	%
Awareness of virtual labs	Yes	5	62	67	35.45
	No	7	115	122	64.55
Use of virtual labs	Yes	5	59	64	33.86
	No	7	118	125	66.14

learners, out of 62 learners who were aware of virtual labs, only 59 (95.16%) used virtual labs. These results suggest that both teachers and learners need to be first aware of virtual labs in order to use them for experiments.

In general, Table 3 also presents the relationship between awareness versus the usage of virtual labs by teachers and learners in the rural public secondary schools. Out of 189 respondents, a total of 67 (35.45%) respondents indicated that they are aware of virtual labs, whereas 122 (64.55%) respondents indicated that they are not aware of virtual labs. Therefore, of those who were aware of the virtual labs, 64 (33.86%) reported using virtual labs. This means three respondents of 67 respondents have not used the virtual lab. As a result, based on the results depicted in Table 3, awareness is linked with the non-use of virtual labs in rural public secondary schools because the results show that 125 (66.14%) have not used virtual labs.

Adoption of virtual labs

Lack of digital devices to use virtual labs

Table 4 presents responses from teachers and learners' perspectives on the lack of digital devices to use virtual labs. The results show a strong overall agreement that access to digital devices is a key challenge for both teachers and learners. The results show that out of 12 teachers, 4 (33.33%) were uncertain, while 5 (41.67%) agreed and 3 (25.00%) strongly agreed that the lack of digital devices affects the use of virtual labs in rural public schools. Comparatively, 177 learners provided their response to the same question. Fifty-five (31.07%) learners were not sure about the effect that digital devices have on the use of virtual labs. On the other hand, 86 (48.59%) agree and 36 (20.34%) strongly agree that the lack of digital devices affects the use of virtual labs in rural public schools. The results show that the lack of digital devices is a significant barrier to the use of virtual labs in rural public secondary schools.

Looking at Table 4, the results show a slight difference between learners and teachers regarding the agreement that the lack of digital devices negatively impacts their adoption. This shows that there is consensus among the teachers and students. Similarly, Figure 1 shows that 39 (20.63%) respondents strongly agree that the lack of digital devices affects the adoption of virtual labs in rural public secondary schools, while 91 (48.15%) agree that the lack of devices could affect the adoption of virtual labs. On the other hand, 59 (31.22%) respondents were uncertain whether the lack of digital devices affects the adoption of virtual labs in rural public secondary schools.

TABLE 4: Lack of digital devices to use virtual labs.

Measures	Teacher	Learners	Total	
			Frequency	%
Strongly disagree	0	0	0	0.00
Disagree	0	0	0	0.00
Uncertain	4	55	59	31.22
Agree	5	86	91	48.15
Strongly agree	3	36	39	20.63

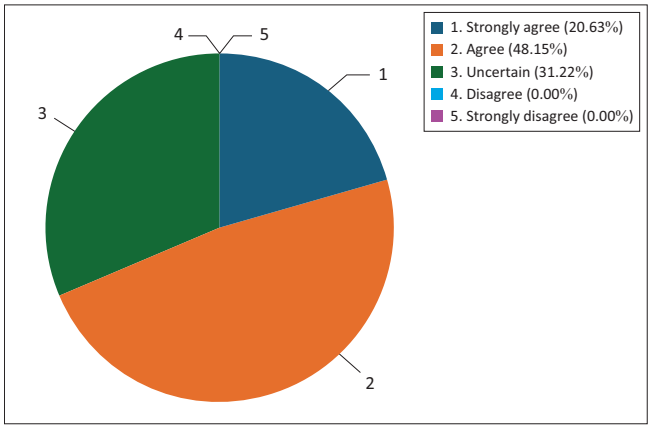

FIGURE 1: Lack of digital devices to use virtual labs.

TABLE 5: Virtual lab maintenance cost.

Measures	Teacher	Learners	Total	
			Frequency	%
Strongly disagree	0	0	0	0.00
Disagree	0	0	0	0.00
Uncertain	4	56	60	31.75
Agree	6	104	110	58.20
Strongly agree	2	17	19	10.05

Virtual labs maintenance cost

The results, as depicted in Table 5, show that out of 12 teachers, only 4 (33.33%) were uncertain that virtual lab platform maintenance costs are very high. On the other hand, 6 (50.00%) agreed, while 2 (16.67%) strongly agreed that the maintenance costs of the virtual labs are very high. While looking at 177 learners, 56 (31.64%) of them were uncertain that the maintenance cost of virtual labs is high. In contrast, 104 (58.76%) agreed and 17 (9.60%) strongly agreed that the maintenance cost of virtual labs is high. Therefore, the results show the consensus among the students that maintaining a virtual lab platform is expensive.

Furthermore, the researchers explored the maintenance cost of virtual labs. The research found that the majority of 110 (58.20%) respondents agree that it is expensive to maintain virtual labs in rural public schools, while 19 (10.5%) respondents agree that it is costly to maintain virtual labs. On the contrary, Figure 2 shows that 60 (31.75%) respondents were not sure whether it is expensive to maintain a virtual lab in rural public schools or not.

Virtual lab training

In Table 6, 1 (8.33%) out of 12 teachers indicated that they are not sure about the effect that training will have on the

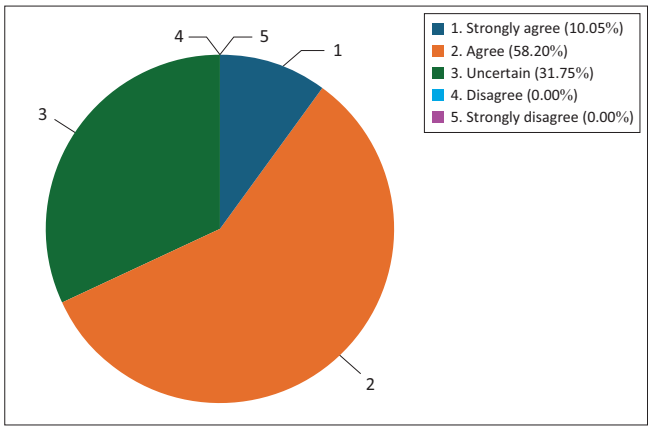

FIGURE 2: Virtual lab maintenance cost.

TABLE 6: Virtual labs training.

Measures	Teacher	Learners	Total	
			Frequency	%
Strongly disagree	0	0	0	0.00
Disagree	0	0	0	0.00
Uncertain	1	0	1	0.53
Agree	3	56	59	31.22
Strongly agree	8	121	129	68.25

adoption of virtual labs in rural public secondary schools. But 3 (25.00%) of them indicated that they agree with the notion that virtual lab training will have a positive influence on the adoption of virtual labs in rural public secondary schools, while 8 (66.67%) strongly agree. On the other hand, out of 177 learners, 56 (31.64%) agreed and 121 (68.36%) strongly agreed that training will have a positive effect on the adoption of virtual labs. Combined, the results show that 188 (99.47%) believe that training will have a positive impact on the adoption of virtual labs.

In Figure 3, a total of 129 (68.25%) and 59 (31.22%) respondents strongly agree and agree that virtual lab training may promote the adoption of virtual labs in rural public secondary schools. However, 1 (0.53%) was uncertain about whether the training will influence the adoption of virtual labs by both teachers and learners in rural public schools.

Lack of awareness of virtual labs

Figure 4 reveals that 22 (11.64%) respondents strongly agree that lack of awareness may hinder the adoption of virtual labs by learners and teachers in rural public secondary schools and 112 (59.26%) agree that lack of awareness may affect the adoption of virtual labs. On the other hand, 55 (29.10%) respondents were uncertain whether awareness would influence the adoption of virtual labs in rural public secondary schools. The results in both Figure 4 and Table 7 show a consensus among the respondents that a lack of awareness can impede the adoption of virtual labs in rural public secondary schools.

Discussion

The objective of this investigation was to identify factors that affect the adoption of virtual labs in rural secondary

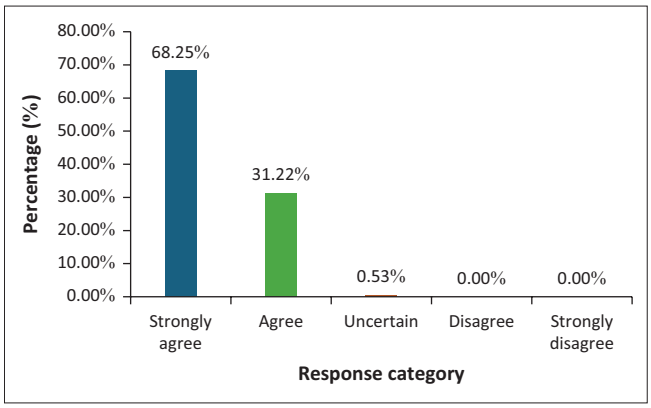

FIGURE 3: Virtual labs training.

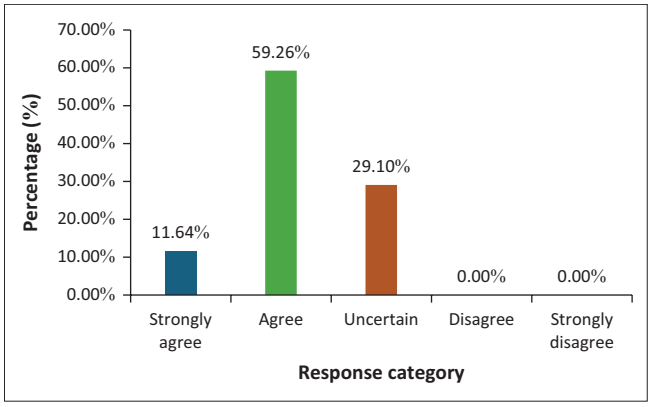

FIGURE 4: Lack of awareness of virtual labs.

TABLE 7: Lack of awareness of virtual labs.

Measures	Teacher	Learners	Total	
			Frequency	%
Strongly disagree	0	0	0	0.00
Disagree	0	0	0	0.00
Uncertain	3	52	55	29.10
Agree	6	106	112	59.26
Strongly agree	3	19	22	11.64

public schools. This objective was achieved by analysing collected data, which revealed that the majority of participants were young, aged between 17 years and 20 years. Participants' age may be linked to exposure to virtual labs. Young people, like learners from rural areas who mostly rely on information shared by teachers, might affect the awareness of new innovations (Mashau & Mokwena 2017; Nzabahimana et al. 2024).

However, the results revealed a good mix of genders for all participants. Furthermore, all the participants had access to the internet, which other studies identified as a significant element in adopting digital tools (Shambare & Jita 2025c). On the other hand, the results revealed a good mix of teaching experience and technological or digital skills. The literature suggests that digital or technological skills are important in adopting innovations such as virtual labs (Musarurwa 2025). Therefore, the results suggest that digital skills cannot be seen as a factor that could affect the effective adoption of virtual labs in rural areas.

During the assessment of factors affecting the adoption of virtual labs in rural public secondary schools, the following were identified as crucial: (1) a lack of awareness, and (2) a lack of digital devices, maintenance costs and training. The majority of participants in this study reported not being aware of virtual labs. This is believed to be the reason for the low adoption of virtual labs in rural public secondary schools. These findings are supported by the studies of Achuthan et al. (2020) and Mashau (2016), which emphasised that for users to adopt digital tools, they must first be aware of them.

Furthermore, this study found that most of the participants reported that the lack of digital devices is one of the factors that affect the effective adoption of virtual labs in rural public secondary schools to conduct science subject experiments. A study by Musarurwa (2025) asserts this result. Most participants also reported that maintenance costs are another factor that could influence resistance to adopting virtual labs in rural public schools. Lastly, the majority of the respondents reported that in order to adopt virtual labs in rural public schools, both learners and teachers must be trained. This finding is supported by Mashau (2016), who indicates that if users are not trained to use digital tools, they are unlikely to adopt them. On the other hand, if users are trained to use digital tools, they are likely to see the benefits of the tool and adopt it (Rogers, 2003).

Overall, the results suggest a strong positive relationship between awareness and usage of virtual labs. Most participants who were aware of virtual labs adopted them to conduct experiments in science subjects in rural public secondary schools. This suggests that awareness is pivotal to the adoption of virtual labs.

Conclusion

This study investigated the factors affecting the adoption of virtual laboratories in rural public secondary schools. The findings indicate that despite the potential of virtual labs to enhance science education, their adoption remains low. The study found that factors such as a lack of awareness, a lack of digital devices, maintenance costs and training are interlinked with the low adoption of virtual labs in rural public secondary schools.

This study found that awareness of virtual labs by teachers is around 40% and by learners is below 40%. Yet, looking at both groups, awareness is at 35.45%. Therefore, to increase awareness among both groups, this study recommends that the Department of Basic Education and its stakeholders must prioritise organising awareness workshops aimed at making rural public-school learners become acquainted with virtual laboratories and their significance in online science experiments. This recommendation is made because many learners in rural public schools are likely unaware of what virtual laboratories are and how they may contribute to the educational process. Thus, there is a need to increase the awareness of the target population about this digital tool and show them how much they stand to gain from using virtual labs.

Furthermore, nearly 100% of respondents agree that training can play a significant role in the adoption of virtual labs in rural public schools. Therefore, the Department of Basic Education should engage in efforts to provide training for both teachers and learners on how to properly use virtual labs. Training is a significant factor in the successful adoption of digital technologies. Ndou, Mashau and Chigada (2023) confirm that training plays a very crucial role, as it enables users to adopt the technology and effectively use it in learning environments. Training should be provided to learners from lower grades for them to learn about the use of virtual laboratories at an earlier age, because this will make it easier for them to acquire the required skills for the efficient utilisation of these digital tools as they reach higher grades.

On the contrary, there is still room for further research into issues relating to the adoption and usage of virtual laboratories by the target population. Future researchers could conduct studies on aspects such as the availability of relevant infrastructure and cybersecurity issues related to the adoption of virtual labs, among others.

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Competing interests

The authors, Prudence T. Ndou; Willard Munyoka and Nkhangweni L. Mashau, declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Prudence T. Ndou: Conceptualisation, Data curation, Formal analysis, Methodology, Project administration, Resources, Writing – review & editing. Willard Munyoka: Conceptualisation, Project administration, Supervision, Validation, Writing – review & editing. Nkhangweni L. Mashau: Conceptualisation, Data curation, Formal analysis, Methodology, Project administration, Software, Supervision, Validation, Visualisation, Writing – original draft, Writing – review & editing. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are not openly available and are available from the corresponding author, Nkhangweni L. Mashau, upon reasonable request.

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