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Virtualizing Practical Science Education: A Sociological Analysis of Undergraduate Teaching and Learning

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Abstract

Objectives: The study aims to investigate the perspectives of university teachers and students on integrating practical science teaching with virtual learning in a multicultural and diverse society, specifically within the context of southwestern Nigeria.

Methods: A mixed-methods approach was employed, involving data collection from 100 university lecturers and 400 undergraduate students across 10 universities. Qualitative data were gathered through semi-structured interviews with lecturers and focus group discussions with students. Quantitative data were obtained via structured questionnaires, allowing for triangulation and comprehensive analysis.

Note: We acknowledge all the stakeholders who participated in this study.

Results: Findings revealed that certain lecturers showed preferential support influenced by students' cultural backgrounds or academic behavior during practical sessions. Additionally, students' educational foundations and the presence of peer support were significant determinants of their success in practical science activities. Virtual learning was seen as a valuable supplement but not a replacement for hands-on experiences.

Conclusion/Implications: The study underscores the critical interplay between instructors, peers, educational technologies, and cultural context in shaping equitable and effective science education. It advocates for a holistic and inclusive approach that integrates practical and virtual modalities while addressing socio-cultural dynamics to enhance student development and ensure quality in tertiary science education.

Keywords: *undergraduate, education, practical science teaching, virtual learning, sociological, perspectives, science education*

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Introduction

Practical science teaching plays a crucial role in enhancing learners' understanding of complex scientific concepts and knowledge, serving as an effective approach for making abstract theories tangible, while equipping both teachers and students with essential scientific skills and competencies (Shana & Abulibdeh, 2020). Practical science teaching can be implemented in both physical and virtual classroom settings. And practical methods also promote quality education, equitable learning opportunities, and improved comprehension of scientific knowledge, which are critical for fostering global citizenship (United Nations, n.d.).

In linguistically diverse communities, collaborative engagement in practical science classrooms ensures equal access to knowledge, which is particularly significant in tertiary education, where students must develop skills for personal growth, innovation, and negotiation within multicultural environments. Globally, efforts have been made to equip tertiary institutions—especially in regions such as Europe, the United Arab Emirates, Asia, and Africa—with the necessary tools, infrastructure, and professional educators to support practical science learning (Oluwasegun & Oluwaseun, 2023). These provisions aim to enhance lifelong learning, social development, and innovation through information and communication technology (ICT)-enriched classroom interactions, improving both access and quality of education (United Nations, n.d.).

In Nigeria, tertiary education emphasizes equipping students with the skills needed for understanding and engaging in both formal and informal education (NPE, 2020). Communication in native languages often strengthens bonds among students, leading to better educational outcomes. However, many science students lack the practical skills required to meet expectations, especially in multicultural settings (Kapici et al., 2019). Research indicates that students often struggle with acquiring practical science knowledge due to limited access to resources and inequitable learning opportunities (Abdallah & Alkaabi, 2023; Shana & Abulibdeh, 2020), resulting in knowledge marginalization where unequal access to science education creates disparities in students' capacities and competencies. Addressing this inequality would likely enhance the overall quality of university education.

Several factors contribute to knowledge marginalization. First, some tertiary students lack the necessary cognitive resources to meet learning expectations due to unsolved societal challenges. Second, inadequate classroom infrastructure and developmental strategies limit students' access to knowledge. Third, educational policies, particularly those governing classroom interactions, may reinforce inequalities.

In Nigeria, where over 525 languages are spoken (Akindele et al., 2022), public university classrooms reflect this linguistic diversity. Overcrowding, a common issue in government-owned institutions, often leads to cultural and linguistic disadvantages for students when English—often a second language—is the primary medium of instruction (Andries et al., 2022). As a result, students may struggle to grasp scientific concepts due to limited access to cognitive resources (Forde & OBrien, 2022).

In practical science classrooms, investigating the roles of teachers, students, and society is essential for understanding how interactions shape science learning. Students bring diverse backgrounds, experiences, and interests that influence their ability to connect with peers and teachers in a shared learning environment (Pruitt-Britton et al., 2022). Student-centered pedagogical approaches, rather than teacher-centered methods, encourage meaningful interactions that facilitate knowledge acquisition. These interactions serve as valuable learning resources, enhancing students' academic performance. However, there remains a gap between policy expectations and actual student outcomes, highlighting a mismatch between available support and required skills.

Modern pedagogical practices increasingly integrate technology into learning interactions. Virtual learning has proven beneficial for practical science education, enhancing comprehension and fostering a sense of belonging and self-efficacy (Hussain & Jones, 2021). The importance of virtual learning became particularly evident during the COVID-19 pandemic, yet access to technological resources remains unequal, particularly in sub-Saharan Africa. Socioeconomic disparities further limit students' ability to engage with online practical science lessons, reinforcing educational inequalities (Henderson & Loreau, 2021). Without equal access to technology, students experience reduced interaction in virtual science classrooms, restricting their learning opportunities.

Literature Review

There is limited interaction in today's science classrooms (Wilmes & Siry, 2018). However, African learners—known for their communal and expressive nature—often engage in group activities, particularly in public institutions (Swart & Janeke , 2022). The number of students per group is often determined by the availability of laboratory materials, which is largely dependent on financial resources. Consequently, the socioeconomic status of students influences the quality of education they receive, with private institutions typically offering better-equipped laboratories than public universities (Lasisi & Adetunji, 2020; Upahi & Oyelekan, 2020).

Despite significant research on high school practical science (Babb & Stockero, 2020; Ferreira & Morais, 2020; Shana & Abulibdeh, 2020), fewer studies have focused on student interactions in tertiary-level practical science courses, particularly in sub-Saharan Africa (Constantinou, 2022; Constantinou & Fotou, 2020) and Nigeria (Kubo et al., 2013; Musah & Umar, 2017; Yeboah et al., 2019). Addressing these gaps aligns with the United Nations' Agenda 2030, which emphasizes quality education and equitable access to technological resources.

From a constructivist perspective, learning is a co-constructive process in which students actively engage in knowledge-building (Borge et al., 2020). Interactions in the practical science classroom enhance understanding, allowing students to integrate their experiences, background knowledge, and interests (Hanum, 2017; Kwaah et al., 2023). Students who participate in knowledge co-creation during classroom discourse are better prepared for online learning. However, barriers to interaction, whether imposed by teachers, peers, or societal structures, can lead to learning inequalities.

To promote equitable education, university students should have access to cognitive resources—both inside and outside the classroom—that are supported by structured learning environments. Unequal access to these resources creates disparities in knowledge acquisition and skill development, particularly when ICT is involved. Blended learning, which integrates virtual experimentation in science laboratories, has been shown to enhance students' laboratory experiences and improve comprehension of scientific concepts (Byukusenge et al., 2022; Castro, 2019; Eliyawati et al., 2021). Virtual laboratories offer flexibility, interactivity, and accessibility, removing the constraints of face-to-face learning. However, students without access to technological resources are often excluded from these opportunities, exacerbating educational inequalities.

The hands-on, minds-on approach remains crucial in practical science education, yet many students face barriers due to socioeconomic limitations. In sub-Saharan Africa, financial constraints often hinder students from engaging in virtual learning, which can impact their sense of inclusion and interaction with peers (Dung, 2020). Vygotsky & Cole (1978) emphasized that social interaction plays a fundamental role in learning. When students are encouraged to ask questions and engage in discourse, their cognitive development is enhanced. Meaningful conversations, supported by social and cultural contexts, facilitate deeper learning. Parents, teachers, peers, and technology serve as More Knowledgeable Others (MKOs), providing knowledge support to students. These interactions enable students to access educational resources and develop essential skills.

In practical science classrooms, students often communicate in their native languages while conducting experiments. However, restrictive language policies in some contexts limit students' ability to leverage their linguistic resources for learning, which can lead to disengagement from science education. Additionally, disparities in access to information and communication technology (ICT) resources mean that some students perform better than others based on the support they receive. When students are denied access to technological tools or discouraged from using their native languages in learning, they may struggle to grasp scientific concepts effectively. Since learning is an interactive process, the role of MKOs—including teachers, peers, and digital resources—is essential in shaping student outcomes.

Purpose and Research Questions

This study critically explores teacher roles in reproducing inequalities in the practical science classroom and the knowledge-support channel that is available to the students. The study also seeks to assess the obstacles to virtual and face-to-face interaction in practical science and proffer solutions towards the challenges and to address the following research questions.

1. What knowledge-support channels are available to the students in the practical science classroom, especially during interactions?
2. What are the challenges encountered by the teachers and students in multicultural and diverse society on teaching practical science virtually?
3. What are the possible suggestions towards improving positive students' outcomes in practical science?

Methods

Study Context and Participants

Both quantitative and qualitative research methods were employed to collect data from participants in this study. The sample consisted of 100 university teachers and 400 first-year university students, selected from 10 universities in Southwestern Nigeria, including six federally owned and four state-owned institutions (see Table 1). This study utilized a purposive sampling technique, as it specifically targeted university teachers who instruct first-year students in practical science courses (physics, chemistry, and biology). These instructors also teach diploma, part-time, and sandwich-degree students within the same laboratory settings. On average, the participating university teachers had approximately 10 years of experience in practical science instruction, dating back to their initial employment as laboratory-based science educators. Practical sessions for chemistry, biology, and physics courses were typically held once per week. These characteristics were deemed essential for inclusion in the study.

Table 1. *Key Characteristics of the Respondents and the Participating Universities*

	University Teachers (T)		**Undergraduate Students (S)**		**Total Participants (*n*/%)**
	M (*n*)	F (*n*)	M (*n*)	F (*n*)	
Federal Universities (*n* = 6)	45	15	110	130	300 (60%)
State Universities (*n* = 4)	30	10	75	85	200 (40%)
Total M/F	**75**	**25**	**185**	**215**	**M = 260/F = 240**
Total T/S	**100**		**400**		**500**

Note: T = teachers; S = students; M = male; F = female.

In accordance with ethical guidelines in Nigerian higher education institutions, faculty members are not required to seek approval from a university ethics committee for studies involving adult participants. However, informed consent was obtained from all respondents. University teachers provided written or oral consent via email, while students received consent forms through email and returned their responses either electronically or in person during practical class sessions.

Instrumentation

A mixed-methods approach, integrating both quantitative and qualitative techniques, was employed to collect data from study participants. The primary data collection instruments included structured questionnaires and semi-structured interviews. A semi-structured questionnaire was developed, incorporating a 5-point Likert scale response format, allowing participants to indicate their level of agreement with each statement: *Strongly Agree*, *Agree*, *Undecided*, *Disagree*, and *Strongly Disagree*.

Survey Protocols

A survey was administered to 400 undergraduate students (46% male with a median age of 18 years old) and 100 university lecturers. Participants were informed about the study's objectives and the nature of discussions that might arise from their participation. Many of the students and lecturers demonstrated a strong interest in contributing to the research. The survey questions were designed to elicit responses regarding student interactions within practical science groups and experiences with virtual learning.

Prior to administering the close-ended questionnaire, a pilot study was conducted at a university not included in the main study. This preliminary study ensured the validity and reliability of the research instruments and provided insights into the scope of the study.

Interview Protocols

Interviews were conducted with both students and lecturers in a semi-structured format, allowing for flexible and conversational engagement. Each interview was guided by five key questions and focused on intra-group and inter-group interactions within the practical science sessions. The face-to-face interviews lasted approximately 10–15 minutes.

Among the student participants, Heads of Groups (HoGs) from the practical science groups volunteered to be interviewed, which was based on their initial responses to the closed-ended questionnaire. Each practical group comprised five to six members. Interview responses were audio-recorded, transcribed, and coded into thematic categories, alongside data collected from open-ended survey responses.

Data Validation and Triangulation

To enhance the credibility and trustworthiness of the study, a triangulation approach was adopted. Member checking was conducted to validate the interpretations of the data. This process was carried out openly, allowing all research team members to assess the consistency of the findings. Given the linguistic diversity among participants, interviews were conducted in English, Yoruba, and Igbo, as respondents were more comfortable expressing certain concepts in their native languages. At least one member of the research team was proficient in two of these three major Nigerian languages.

To minimize potential data distortion, coercing respondents to speak exclusively in English was avoided, as it could have led to participant withdrawal or limited responses. After translation and interpretation, lecturers were provided with the transcribed data for further member checking to ensure accuracy and alignment with their original intent. By this stage of the research process, the researchers had established rapport with the participants, facilitating deeper engagement and enabling follow-up discussions.

Data Analysis

The survey data are presented using descriptive statistics of frequencies and percentages. The interview audio recordings were transcribed and coded into thematic nodes by the researchers. Each confirmed node contained a range of opinions. The quotes used in this study are representative of statement made by several respondents.

Results

Figure 1 presents responses to the question regarding perceptions of student academic performance across different faculties. According to the survey responses, students from the Faculty of Basic Medical Sciences (FBMS) are perceived to perform better academically compared to students from other faculties, including sciences, environmental sciences, engineering, agriculture, and education.

Figure 1. *Perceived Academic Performance of Students According to Faculty*

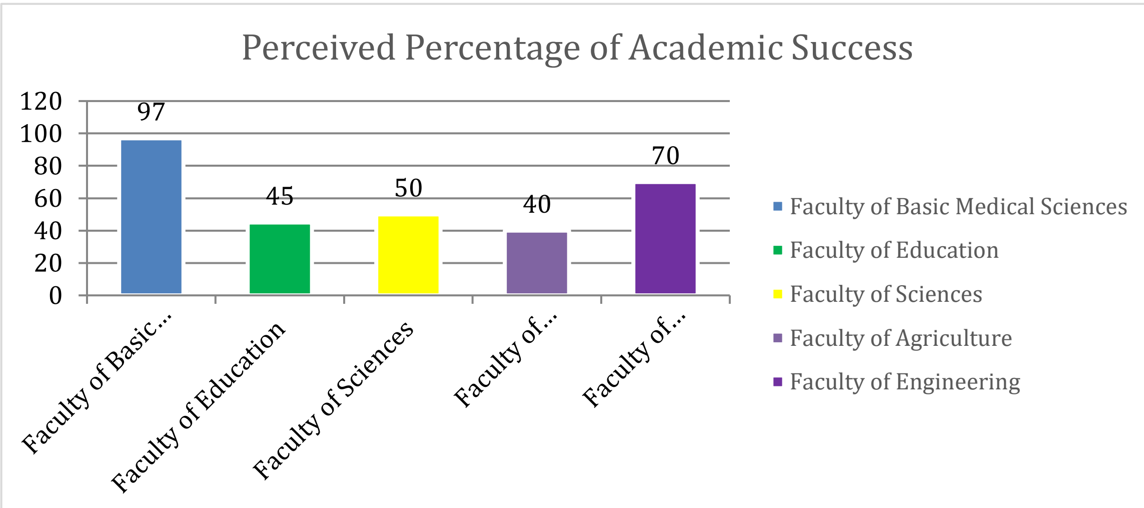


Figure 2 presents university teachers' perspectives on virtual teaching, highlighting both its benefits and challenges. The results indicate that technical issues (such as connectivity problems, software glitches, and other disruptions) are a significant concern, with a considerable proportion of respondents either disagreeing or strongly disagreeing that virtual teaching is seamless. Similarly, many teachers expressed challenges in adapting teaching methods to the virtual platform, suggesting that transitioning from traditional classroom instruction to online learning is not straightforward. However, there is a notable level of agreement that virtual teaching can enhance accessibility for students facing geographical or physical barriers and that it has the potential to improve flexibility and convenience in education. Additionally, some instructors acknowledge that virtual teaching facilitates self-paced learning and personalized instruction, which can benefit students with diverse learning needs.

Conversely, significant challenges are also highlighted in Figure 2. Many respondents agreed that managing distractions and balancing responsibilities during virtual sessions is difficult, and that maintaining student engagement and attention in a virtual setting is more demanding than in a traditional classroom. The lack of face-to-face interaction was identified as a major challenge, as it hinders instructors' ability to gauge student understanding effectively.

Furthermore, the results (see Figure 2) suggest that teaching virtually requires more preparation time compared to traditional classroom teaching. Assessing and evaluating student performance in a virtual setting is also perceived as challenging, and virtual communication with students within the school environment remains a critical issue.

Figure 2. *University Teachers' Perspectives of Virtual Teaching*

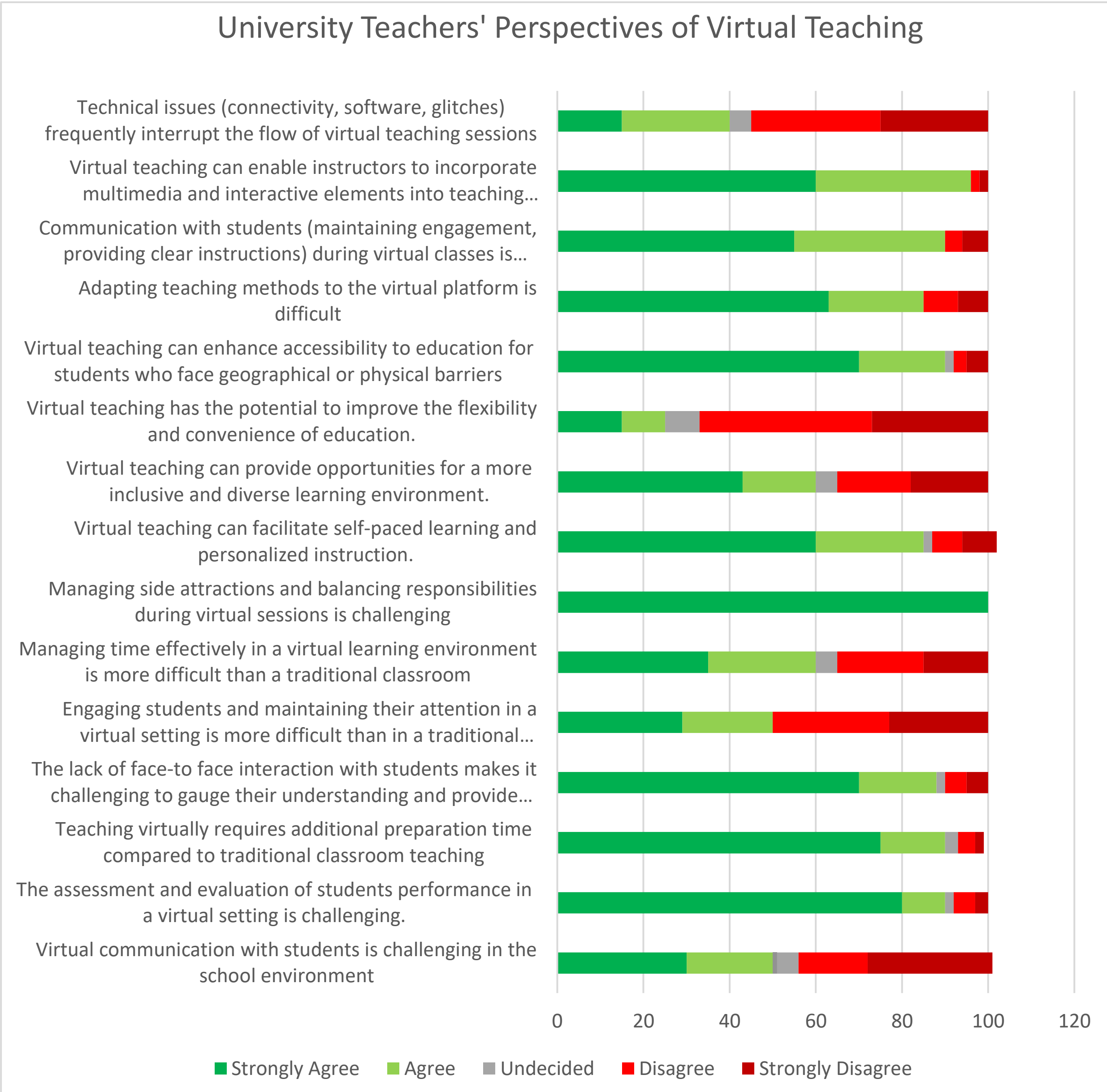


Figure 3 presents the perspectives of university teachers regarding students' attitudes in practical groups, as evaluated through a Likert scale. The figure suggests that university teachers perceive a range of behavioral and academic factors influencing student interactions in practical group settings. Notably, a significant proportion of respondents agree or strongly agree that aggressive (assertive or dominate behavior) students exist in the groups and that tensions arise in some of these groups.

In the context of the university teacher's perception, in Figure 3, "aggressive" refers to dominant or assertive classroom behavior, such as being overly eager to contribute, taking charge in group tasks, or strongly asserting one's opinions, often at the expense of others' participation. Furthermore, teachers acknowledge that some students prefer isolation during practicals.

Regarding supervision, Figure 3 shows that most teachers report actively overseeing group interactions during practical sessions. However, opinions are divided on whether gender influences student performance in practical science sessions, with responses showing notable disagreement. Similarly, the role of socioeconomic background in student performance is debated, as there is substantial disagreement on whether students from low-income households perform better.

Another critical observation (see Figure 3) is the perception of peer influence on academic performance. Many respondents acknowledge that peer interactions affect students' academic outcomes in practical sessions. Likewise, there is a general agreement that brilliant students tend to be more active in responding to questions compared to their peers.

Also, a mixed response is evident regarding teachers' selection of group leaders, with some reporting direct involvement, while others may allow students to self-organize (see Figure 3). The data indicate the complexities of group dynamics in practical sessions, with multiple socio-behavioral and academic factors at play.

Figure 3. *University Teacher's Perspectives on Student's Attitude to Practical Work*

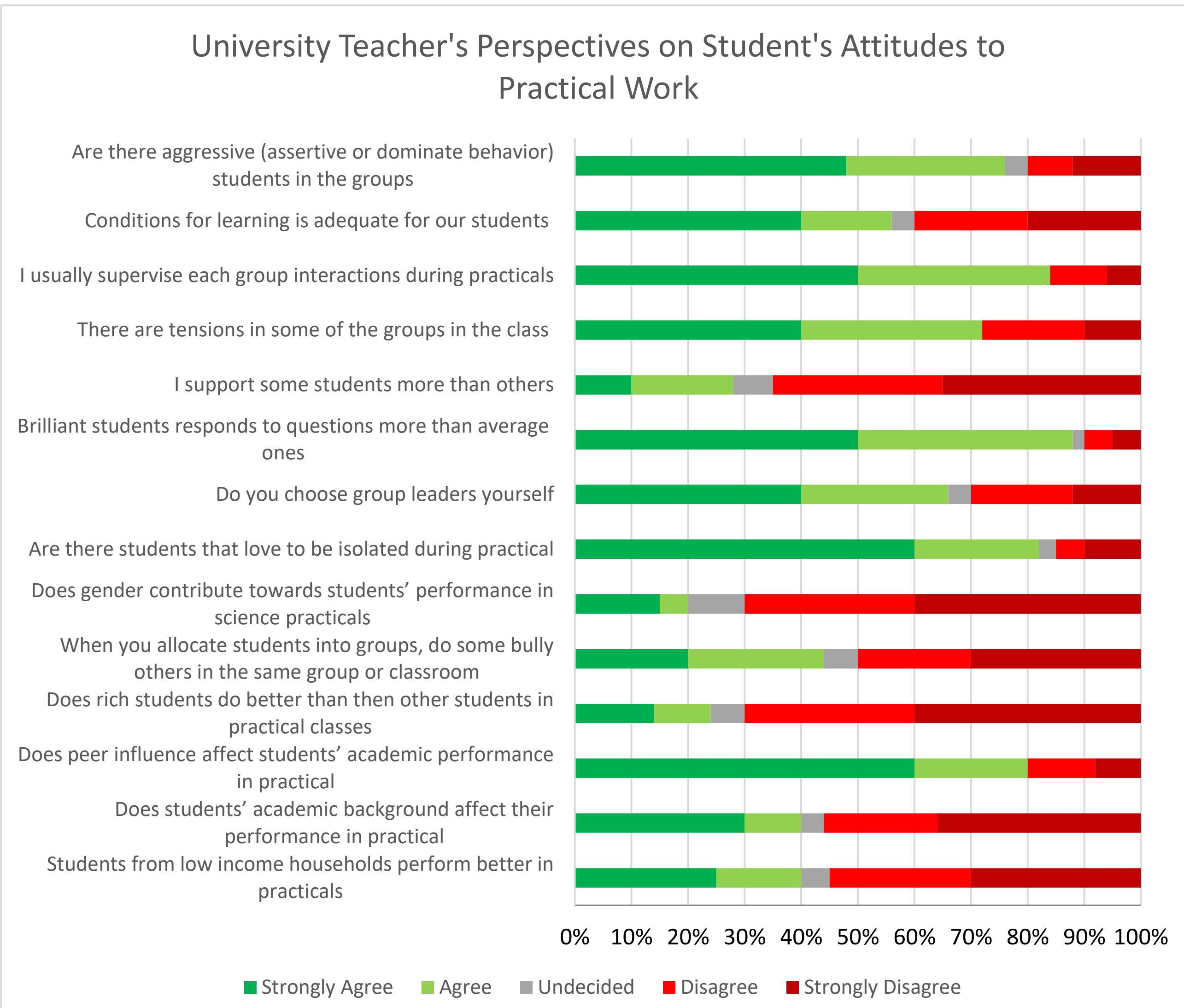
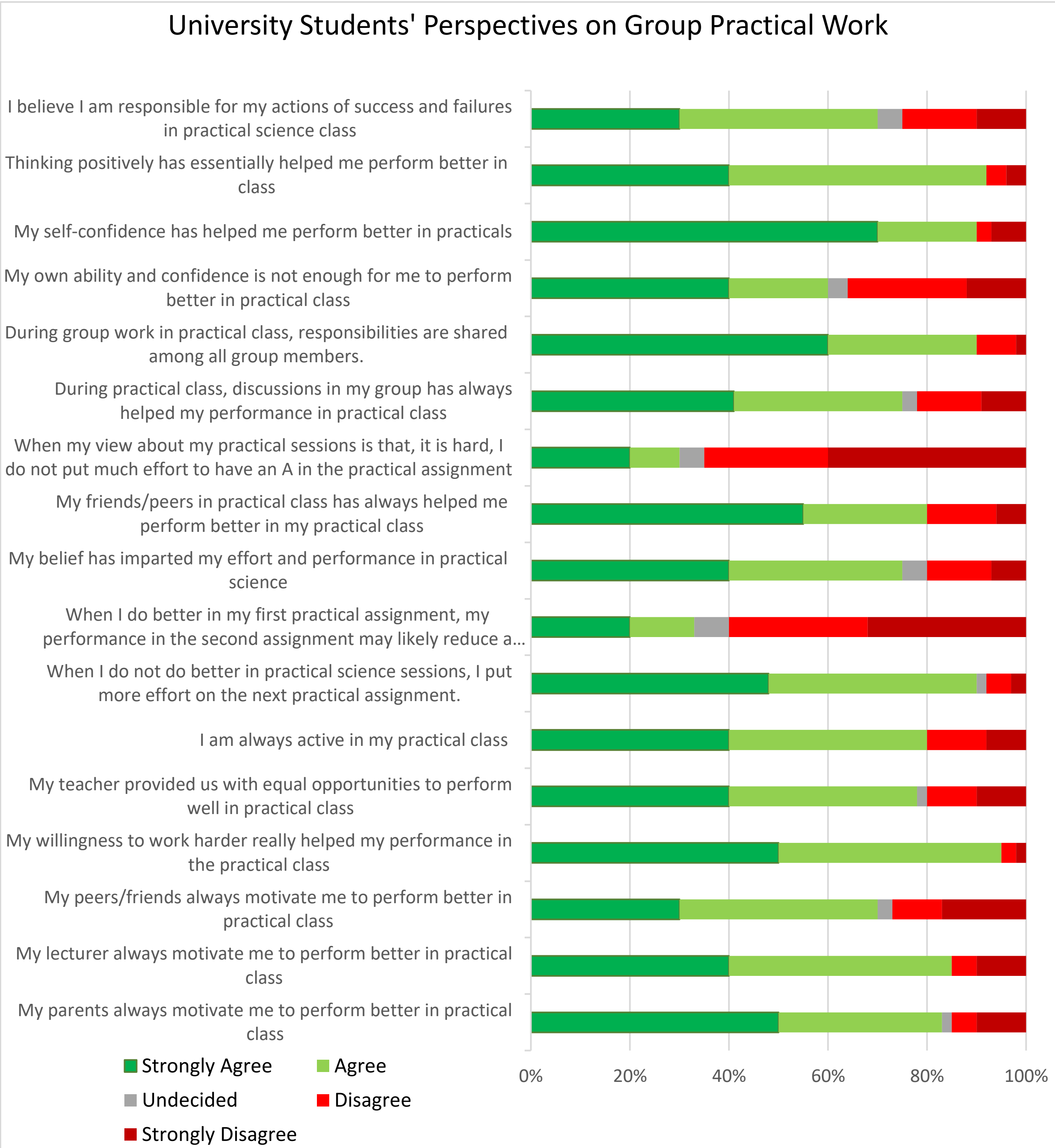


Figure 4 presents university students' perspectives on group practical work. The findings indicate that a majority of students recognize personal responsibility for their success or failure in practical science classes. Additionally, a strong positive perception exists regarding self-confidence, motivation, and peer influence, with many students agreeing that their confidence and positive thinking enhance their performance in practical work. Similarly, peer and teacher support are acknowledged as significant contributors to academic performance, with students reporting that their peers, lecturers, and parents motivate them to excel in practical assignments.

Figure 4. *University Students' Perspectives on Group Practical Work*



Regarding group-work dynamics, Figure 4 shows that many students agree that responsibilities in practical sessions are shared among all group members and that discussions within groups enhance their learning experience. However, some disagreement is observed regarding the sufficiency of individual ability and confidence in achieving high performance, suggesting that external factors, such as peer collaboration and teacher guidance, play a crucial role.

A notable pattern emerges in Figure 4 regarding student effort and performance. Many students indicate that when they underperform in a practical session, they are likely to exert greater effort in subsequent assignments. However, a segment of students also suggests that an initial high performance in a practical assignment may result in a slight reduction in effort for subsequent tasks. The responses further highlight mixed attitudes toward motivation and effort. While a majority agree that their willingness to work harder improves their performance, a small proportion of students express a lack of motivation when they perceive practical assignments as difficult, leading to reduced effort in achieving top grades. Overall, the results suggest that students' attitudes toward practical group work are shaped by a combination of personal attributes, peer influence, and external motivation.

Figure 5 illustrates university students' perspectives on virtual teaching within a university context. The data revealed that students face several challenges with virtual learning. A considerable proportion of respondents indicate difficulties in maintaining motivation and managing time effectively in an online learning environment. Furthermore, access to reliable internet connectivity and necessary resources appears to be a concern for many students, reflecting potential digital divide issues.

Another prominent challenge identified (see Figure 5) is the lack of social interaction and peer collaboration, with a significant number of students expressing dissatisfaction with the level of participation in virtual classes. Similarly, limited interaction with instructors and classmates is a recurring concern, which may impact engagement and learning outcomes. Difficulties in understanding and comprehending course materials in virtual settings are also highlighted as key issues.

Despite these challenges, students recognize some potential benefits of virtual teaching. According to data in Figure 5, many respondents agree that virtual teaching can enhance accessibility to education and enable instructors to adopt flexible teaching strategies. There is also a general acknowledgment that virtual learning has the potential to improve the educational experience, although this perspective is met with varying degrees of agreement. The responses concerning workload and assignments in virtual classes present mixed opinions. While some students find the workload manageable, others perceive it as overwhelming. Additionally, the difficulty in maintaining motivation and managing time effectively within virtual learning environments is a recurring concern.

Overall, the findings in Figure 5 emphasize both the advantages and limitations of virtual teaching in higher education. While students acknowledge the potential of online learning to enhance accessibility and instructional flexibility, challenges related to engagement, interaction, motivation, and resource availability remain significant. These results suggest a need for institutional interventions to enhance the effectiveness of virtual learning by addressing technological barriers, promoting interactive teaching methodologies, and ensuring adequate student support mechanisms.

Figure 5. *Students' View of Virtual Teaching in a University Context*

Analysis of Interview Data

Interview responses were collected in this study to supplement the findings from the close-ended survey questions. These responses were systematically analyzed and categorized into themes through coding. The key themes identified include peer support and dissonance, community support, teacher support, technological support, and challenges of virtual learning.

Peer Support and Dissonance

Student responses indicate that peer influence plays a significant role in their learning processes. Many students acknowledged that their background knowledge in science and related subjects facilitated their cognitive engagement in group work. Representative responses from students include:

- *"The ability to link theory with practical sessions in the laboratory, along with attentiveness to laboratory rules and instructions, is crucial in ensuring positive learning outcomes."*
- *"Since practicals are conducted in groups, when the high-achieving students in the group display a positive attitude toward laboratory activities, other members tend to follow suit."*
- *"Students from the Faculty of Basic Sciences tend to perform better than students from other faculties, possibly due to differences in academic orientation."*
- *"As a student, I often relate what I am taught in class to objects at home. When I return home, I examine and interact with them, which reinforces my learning. Occasionally, I even bring these objects to school for further exploration."*
- *"Students' success in science practicals depends on their focus, basic understanding of the subject, and level of effort and study habits."*
- *"Some groups perform better than others because certain members receive additional support from teachers and society."*
- *"As a student, I often rely on supernatural guidance to deepen my understanding of science concepts."*
- *"Group work fosters collaboration, allowing students to share ideas. At home, I also receive assistance with my homework from family members."*
- *"Many times, when I am introduced to a new science topic, I link it to prior knowledge gained at home, where my brothers and uncles often teach me."*

However, while peer support is prevalent, students also reported issues of dissonance within the practical science classroom. Some first-year university students highlighted tensions that arise in group interactions, as reflected in the following statements:

- *"Some students engage in bullying when they do not receive the support they expect from their peers. Often, they pressure others to complete assignments or explain difficult concepts for them. This behavior may extend beyond the practical classroom setting."*
- *"Some students display different attitudes toward hard work, assuming dominant roles within groups and classrooms, which can create conflicts."*

Community Support

Students also bring external cognitive support from their communities into the classroom environment. Some of the representative statements from students include:

- *"My uncle and cousins assist me with mathematics at home. When I receive assignments in the practical science laboratory, I consult them for help."*

- *"My elder brothers conduct local experiments at home. Observing their activities helps me recall lessons when similar concepts are introduced in school."*
- *"Certain materials used as instructional aids in school are also found in my home, which reinforces my learning."*

Teacher Support

Teacher support was identified as a crucial factor in student learning experiences. Students shared the following insights:

- *"Our teacher sometimes instructs us to complete assignments individually or in groups."*
- *"Whenever I feel confused during practical science lessons, my teacher provides explanations to clarify my understanding."*
- *"My teacher tends to support certain students more than others, possibly because they require additional guidance compared to their peers."*

Technological Support

Students recognized the internet as an essential tool for accessing scientific knowledge and enhancing their understanding of practical science. The following responses highlight this theme:

- *"I frequently use the internet to clarify concepts I do not understand in science practicals. YouTube, in particular, has numerous instructional videos."*
- *"My mobile phone enables me to continue learning scientific concepts outside the classroom. When I lack internet data, I sometimes use my father's phone."*
- *"As a teacher, technology has significantly enhanced my lesson delivery. I utilize online resources and animations to engage students and facilitate understanding."*

Challenges of Virtual Learning

Both university science instructors and students acknowledged the potential benefits of virtual learning for practical science education. However, they also identified several challenges, as illustrated by the following representative statements:

- *"We are not familiar with instructions on the applications (simulation and remote). The language is foreign to us and in a way, they appear to re-colonize us. It is not culturally accommodating."*
- *"Students and teachers frequently complain about inadequate internet connectivity, which negatively affects students' perceptions of virtual learning."*
- *"Facilities required for effective virtual learning, such as hardware resources, internet access, and computers, are not widely available. Socioeconomically disadvantaged students struggle to access these resources, and government support is insufficient."*
- *"Unequal access to cognitive support from teachers affects students' ability to view virtual learning positively."*

- *"Many students are unable to fully participate in virtual learning due to competing responsibilities, such as farming and household chores, especially after school hours."*
- *"I cannot ascertain whether my students acquire practical knowledge effectively in a virtual learning environment, as online learning often leads to divided attention and poor time management. I prefer blended learning, which combines virtual and face-to-face instruction."*
- *"Western-designed virtual learning applications do not cater to our cultural context, making them less user-friendly. We need applications that are more culturally relevant."*

University lecturers also expressed concerns regarding the challenges they face in implementing virtual learning for science practicals. Some of their statements include:

- *"The willingness and mindset of university teachers toward virtual learning play a crucial role in enhancing its effectiveness for science practicals."*
- *"University laboratories are overpopulated, causing strain on facilities. Additionally, online groups are difficult to monitor effectively."*
- *"Lecturers need to develop ICT literacy skills to facilitate students' understanding of virtual science practicals."*
- *"Some teachers cite financial constraints as a barrier to acquiring the necessary hardware for virtual learning."*
- *"Students complain that university instructors do not provide adequate engagement in virtual classes and that feedback is often delayed."*

To improve the effectiveness of virtual learning in practical science education, respondents suggested the following interventions:

- *"The university should provide free Wi-Fi and subsidized internet data for both students and teachers."*
- *"A more interactive virtual support system should be developed to enhance communication between university teachers and students."*

Discussion

The findings of this study provide a comprehensive basis for discussion and interpretation in the context of practical science education. Respondents identified multiple forms of support and facilitation necessary for students to achieve positive outcomes in practical science teaching. The discussion is structured around key themes that emerged from the study, offering critical insights into the perspectives of university teachers and students regarding the use of virtual teaching and learning in higher education settings.

This study addresses three key research questions:

- RQ1. What knowledge-support (capital) channels are available to students in the practical science classroom, particularly during interactions?
- RQ 2. What challenges do teachers and students face in a multicultural and diverse society regarding virtual practical science education?

- RQ 3. What strategies can be implemented to improve student outcomes in practical science?

Research Question 1: Knowledge-Support (Capital) Channels in Practical Science Education

Peer support emerged as a primary enabler in students' learning processes within the science classroom to answer RQ1, which asks: "What knowledge-support (capital) channels are available to students in the practical science classroom, particularly during interactions?"

Findings indicate that students receive various forms of support from teachers, society, parents, and peers. However, structured peer interactions within the laboratory setting are the most accessible (100%) and align with the findings of Altermatt (2019) and AbdElmagied Elsayed et al. (2023), who assert that peer support positively influences student academic outcomes. Peer support fosters shared learning responsibilities and contributes to students' academic success.

Grouping structures, within practical science classrooms, significantly impact students' access to peer support. However, virtual learning introduces apprehensions regarding interaction levels, particularly within multicultural settings. Some students experience social isolation (Gillett-Swan, 2017) and express concerns about participating in online group activities. As a potential solution, multicultural communities offer alternative spaces for peer interactions, including places of worship, marketplaces, and community gatherings. Additionally, online communities provide continuous collaboration opportunities. Peer support, therefore, functions as both a cultural enhancer and an enabler of learning.

The study further suggests that students' self-confidence and beliefs influence their willingness to engage in shared learning responsibilities. These beliefs are shaped by their cultural capital, which impacts students' self-efficacy and academic performance.

Tensions in the Science Classroom

Some students expressed a preference for independent participation in practical sessions, which may be linked to underlying psychological issues, bullying, or classroom tensions. Findings indicate that students who engage in aggressive or competitive behaviors contribute to disruptions in practical science sessions. Additionally, unequal distribution of cognitive resources among students leads to increased competition, conflict, and tension. Teachers may inadvertently exacerbate these issues if their instructional support is not equitably distributed. Proper supervision and structured interventions are necessary to address these challenges effectively.

Community Enablements

The study highlights the role of community support in practical science education. Many students (83%) reported receiving substantial academic support from parents or guardians, reinforcing the importance of community involvement in education. Teachers are encouraged to extend their instructional responsibilities to include collaboration with parents and guardians, who can serve as More Knowledgeable Others (MKOs) to enhance student learning.

Background knowledge, brought into the classroom by students, is often underutilized—particularly in teacher-centered learning environments. A culturally responsive approach to teaching science, which incorporates familiar community artifacts as instructional materials, can enhance student engagement and comprehension. Additionally, some students rely on spiritual support as a coping mechanism, aligning with Parsons (2008) who posits that spirituality is integral to the ethos of Black learners. Policies should be enacted to formally recognize and integrate community-based learning opportunities to ensure equitable access to educational resources.

Teacher Support

Teachers are central to educational development and play a critical role in shaping student agency and identity. However, findings indicate that some teachers selectively provide cognitive and psychological support to certain students, with 70% of teachers acknowledging disparities in their support distribution. This action is often attributed to factors, such as classroom overpopulation and resource limitations. Addressing these disparities requires structural reforms to ensure equitable teacher–student interactions.

Policy Structures

Policies governing practical science education play a crucial role in structuring group formations and facilitating meaningful discussions. However, some students experience inequalities in accessing teacher, peer, parental, and technological support. As Jiang (2021) posits, educational inequalities reflect broader systemic injustices.

Findings suggest that the implementation of information and communication technology (ICT) policies can provide protections and incentives to enhance virtual learning experiences. Additionally, socio-economic status (SES) significantly influences students' access to quality teacher support, as students from low-income backgrounds often face greater educational challenges due to resource constraints (Hanselman, 2019). Addressing these disparities requires policy interventions to ensure equitable access to cognitive support and educational materials.

Technological Support

Technology plays a vital role in enhancing pedagogical practices. This study reveals that university teachers and students recognize the potential of technology to improve teaching and learning outcomes. However, there remains skepticism regarding its effectiveness in practical science education, as noted by Eslamian and Khademi (2017). While ICT can facilitate lifelong learning and improve educational access, its effectiveness is context-dependent.

The study finds that 90% of students experience difficulties adapting to virtual learning, highlighting the need for enhanced technological support. Practical science education can benefit from the integration of simulations and remote laboratories to complement hands-on experiences.

Research Question 2: Challenges in Virtual Practical Science Education

RQ2 seeks to answer the question: "What challenges do teachers and students face in a multicultural and diverse society regarding virtual practical science education?"

Data show that several challenges hinder the effective implementation of virtual practical science education, including inadequate technological support, limited ICT access among students from low socio-economic backgrounds, and disparities in technological proficiency (Kennedy et al., 2022; Korkmaz et al., 2022). Additionally, the study identifies issues related to poor network coverage, frequent electricity outages, and a lack of faculty expertise in overseeing virtual practical sessions. Addressing these challenges requires investment in digital infrastructure, faculty training, and equitable access to ICT resources.

Research Question 3: Strategies for Improving Practical Science Education

Research Question 3 asks, "What strategies can be implemented to improve student outcomes in practical science?"

Based on the analysis of participants' responses, several strategies were identified to enhance the effectiveness of practical science education in virtual and blended learning environments. These strategies reflect both the structural and cultural factors influencing students' learning experiences. The following recommendations emerged from the data and are proposed for consideration by educators, policymakers, and institutional leaders:

1. Virtual learning platforms should be contextually inclusive, considering historical and cultural sensitivities.
2. Instructional materials should reflect students' cultural backgrounds to enhance engagement.
3. Governments should provide adequate resources (hardware and software) to mitigate socio-economic disparities in education.
4. Policies should be enacted to encourage the integration of virtual learning platforms into pedagogical practices.
5. Educators should implement strategies to strengthen community, teacher, and technological support networks for students.

Conclusion

The acquisition of practical scientific knowledge and skills is critical for quality education and societal development. Despite global education initiatives, such as the United Nations 2030 Agenda, significant gaps remain in equitable access to practical science education.

This study identifies key barriers, including inadequate resources, classroom inequalities, and limited technological access. The role of teachers in shaping learning environments is particularly crucial, as their cognitive support significantly influences student outcomes. Additionally, peer support emerges as a vital enabler, though its availability depends on structured interactions.

Addressing these disparities requires a comprehensive framework, incorporating teachers, peers, community, and technology (ICT) to ensure equitable and effective practical science education in tertiary institutions. The study did not assess the quality or design of the online and multimedia instructional materials used in the virtual learning environments. Variations in instructional design could significantly influence students' learning experiences and perceptions. Future research could investigate the relationship between the quality of online instructional design and students' perceived workload and motivation.

Conflict of Interest

The authors declare no conflict of interest for this study.

Ethics Statement

Faculty members in Nigeria higher education institutions do not need to seek approval from the University Ethics Committee for studies involving adults. However, the respondents gave their written/oral informed consent to voluntarily participate in the study.

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