

Research

Technology integration in teacher education: challenges and adaptations in the post-pandemic era

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Abstract

COVID-19 pandemic experiences have globally accelerated technology use in higher education, including in developing countries like South Africa. The advancements and use of technology during the COVID-19 lockdown led to increased access to knowledge relevant to educational, professional, and personal development. Nonetheless, difficulties with incorporating technology into teaching and learning remain in teacher education, and there are no real-world examples explaining solutions adapted to reflect South African post-pandemic teacher education. This research, conducted at a public university issues, high levels of plagiarism, and load shedding as challenges faced by pre-service teachers and teacher educators in post-pandemic teacher education. The results highlight the need in South Africa, aimed to understand and exemplify technology adaptations and challenges in post-pandemic teacher education through Vygotsky's social constructivist worldview. Data collected through observation and a focus-group interview session with participants in the Faculty of Education at a university in South Africa revealed technology incompatibility, ad-hoc solutions to socio-economic for continuous, interactive, and practically focused interactions between educators and policymakers, educators and educators, and educators and pre-service teachers to minimize or eradicate obstacles related to technology integration in post-pandemic teacher education programmes.

Keywords Challenges · Pre-service teachers · Technology · Teacher education · Social-constructivism

1 Introduction

Since 2020, there has been a notable increase in technology integration in teacher education programmes [16, 55, 63]. The COVID-19 pandemic triggered a global increase in technology integration in instructional practices, necessitating an increase in the use of technology in teaching and learning activities [15, 63, 87]. This shift has persisted, showcasing technology as an indispensable instrument for teacher education's learning and teaching activities [2].

Globally, university educators are using several technologies to support instruction, knowledge acquisition, and retention [4, 14, 98]. With the ever-evolving nature of technology, educators are now forced to rethink teaching plans to enable pre-service teachers to learn, unlearn, and re-learn subject matter [5, 29, 75]. In this regard, and through this mode, pre-service teachers are encouraged to scrutinise and reflect critically on their existing knowledge, make informed decisions about revising outdated knowledge, and acquire and adopt new knowledge appropriate to changing contexts.

Furthermore, the COVID-19 pandemic expedited the adoption of technology by both teacher educators and students to complete their academic tasks. This trend is expected to continue in teacher education programmes offered in both developing and developed countries [25, 93]. For instance, the use of technologies, such as hi-flex data wireless projectors,

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Bluetooth-enabled speakers, the Internet, open educational resources like Google, YouTube, Quizizz, Kahoot, and Artificial Intelligence (AI), as well as tools like Quill Bot and Grammarly, Chat Generative Pre-Defined Transformer (ChatGPT), and communication software like Zoom Technology and Google Meet have all become active for use in teacher education [27, 33, 84, 87, 102]. Although technology integration in education is now crucial for success, challenges such as inadequate experience and training in the use of technology, a lack of administrative support, and socio-economic gaps hinder the effective integration of technology in teacher education programmes [34, 52].

However, there is variation in technology integration in post-pandemic teacher education, with emerging and contrasting challenges in developing and developed countries. For instance, in a developing country like South Africa, there is a lack of a real-world account of technology integration to exemplify what and how teacher educators and pre-service teachers experience challenges and adaptations of technology in post-pandemic teacher education. In this context, academics like [50, 80, 90, 94] have noted that obstacles to integrating technology into instruction or learning activities both before and after the COVID-19 lockdown include socio-economic disparities, inadequate infrastructure, and attitudinal issues. These studies, however, do not provide real-world examples of experiences highlighting the adaptations in technology integration in South African teacher education during and following the pandemic.

In light of the post-pandemic teacher education context in South Africa, [24, 60, 87] recommend that teacher educators and education stakeholders give careful thought to analysing and resolving these issues. By analysing the challenges and adaptations that South African teacher education programmes experience when they incorporate technology and by placing significant emphasis on educators' viewpoints and experiences, this study seeks to close a gap in both the literature and the practice.

This study, therefore, aims to address the following research question:

- What technology integration challenges are being experienced by some university educators and pre-service teachers in a post-pandemic teacher education programme?

The significance of the research question and the study's execution lies in the ability to define, enhance, and optimize the effectiveness of interventions intended to integrate technology into post-pandemic teacher education programmes in the global South, particularly South African teacher education programmes.

1.1 Trends and impacts of the COVID-19 pandemic on higher education

In December 2019, a group of unknown causes of pneumonia cases in Wuhan, China, were identified [45]. Not too long afterwards, specifically on January 12, 2020, Chinese authorities released the genome sequence of a novel coronavirus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [41]. The disease unexpectedly spread to Europe, America, and Africa, marking the beginning of a global crisis. On March 11, 2020, the widely spread, infectious, and highly contagious coronavirus (SARS-CoV-2) known as COVID-19 was declared a global pandemic by the World Health Organization (WHO) [20].

Businesses and educational institutions closed down in many industrialized and developing nations, forcing people and governments to rethink face-to-face transactions and one-on-one communication [71, 89, 91]. However, the World Health Organization and governments strongly advised the use of technology during these periods, citing it as an unstoppable instrument that is useful for continuing transactions and communication, including online instruction in schools and higher education institutions. This shift to technology was a testament to the adaptability of the education system in the face of a global crisis [62, 67]. The guidance from world governments and the WHO regarding the use of technology in local and global partnerships led to the adoption of various technologies to support institutional operations across all areas of human endeavour [23].

As such, the educational system adopted technology to continue learning and instruction during the pandemic [67], producing notable outcomes but highlighting specific challenges that educators and policymakers in higher education must address in instructional practices. First, to address several societal divides that had not gotten much attention before the pandemic, the COVID-19 pandemic forced the educational system to reevaluate its approaches to teaching and learning in light of global health challenges to accommodate social differences [36]. Second, to keep up with the transition from traditional classroom instruction to technology-enhanced instruction, teacher educators who lack technology integration knowledge must quicken the pace of the technology-integration learning process [83]. Thirdly, the unmet resource deficit among pre-service teachers needs to be addressed if technology is to be used in higher education during and after the epidemic [83].

Although teacher educators and pre-service teachers are obliged to embrace and incorporate technology into their pedagogies and learning purposes due to the abrupt requirement for the new form of pedagogy, complying with institutional and governmental directives on the use of technology to continue teaching and learning during the pandemic era became a new challenge for pre-service teachers and educators [70, 77]. Technologies such as social media platforms for content sharing and Zoom communication software for communicative teaching and learning experiences became a challenge for some pre-service teachers from low-income homes, even though some governments provided free Internet bundles to enable students to participate in online classes [23, 32].

The impact of the COVID-19 pandemic on South Africa's education system and societal relationships is comparable to that of other nations in Africa, Europe, and America. For instance, the pandemic impacted South African people, businesses, and educational institutions [53]. Relying on the Disaster Management Act 57 of 2002, President Cyril Ramaphosa of South Africa proclaimed a national state of disaster [47]. The primary goal of declaring a state of disaster, according to [47] and [49], was to advance an integrated and coordinated system of disaster management, with a focus on prevention and mitigation by governmental bodies at the national, provincial, and municipal levels as well as statutory officials, other role-players in disaster management, and communities [48]. To curb the disease's spread and mitigate its impact on the nation's schools and society, the president of South Africa subsequently issued an order for a nationwide lockdown, which went into effect on March 26, 2020.

Like their global counterparts, the 2020 coronavirus (COVID-19) outbreak in South Africa compelled the Departments of Basic and Higher Education to order that all educational institutions consider the feasibility of replacing in-person teaching and learning processes with online learning and other synchronous and asynchronous technologies [47, 56]. However, instruction during and after the COVID-19 pandemic brought to light issues with the use of technology in South African universities [62]. These included unequal access to technology, unethical behaviour, copywriting and material reuse, and inadequate internet access resulting from South Africa's digital divide [97]. Even after the complete lifting of South Africa's ban on in-person interactions on April 5, 2022, by President Cyril Ramaphosa [58], the problems still exist in higher education and need immediate attention.

In the framework of South Africa's post-pandemic teacher education system, the issues offer opportunities for study to understand pre-service teachers' and teacher educators' experiences with technology adaptation and challenges. In light of this, and as earlier stated, this study aims to comprehend the difficulties and experiences with adaptation that pre-service teachers and teacher educators encounter while integrating or utilizing technology in post-pandemic teacher education.

1.2 Theory of social constructivism

Two interrelated components of the [92] social constructivism theory are considered in this study. These components are social interaction and the use of 'cultural tools' (in the current case, technology) in the knowledge-building process [92]. According to [92], social interaction is crucial to knowledge development in any teaching–learning environment. Based on his research, he made the case that knowledge development should take place in an interactive and participatory environment. [92] Further, it was contended that to make learning concepts easier for learners to understand for self-discovery and knowledge representation, cultural tools can promote social interaction among students and educators. Building on [92] theory, one can argue that active participation in any technology-rich learning environment could influence how technology supports learning activities and academic proficiencies [65, 96].

While social interaction, scaffolding, community of practice, mediation, tools, language, culture, and the Zone of Proximal Development (ZPD) are part of the components of the social constructivist theory, this study focused on social interaction to comprehend the subject under study. Knowledge should be constructed through shared experiences. The foundation of our analysis of the theory's application in this study, as shown in Fig. 1, is that knowledge of technology utilization and challenges can be socially developed through shared individual experiences and perspectives. We equally believe that educators, through social interaction, are highly likely to influence and enhance each other's knowledge regarding the challenges of technology integration in post-pandemic teacher education.

Figure 1 is an illustration of how our use of the theory in our study helped us acquire new knowledge of the kind of transferrable knowledge that would be helpful in the process of identifying and mitigating the challenges of technology utilisation in teaching and learning activities, be it in online or face-to-face instruction [54, 57]. The use of social interaction assisted the educators participating in our study in gaining the information required to recognise obstacles that hinder teachers' and students' use of technology for teaching and learning, whether in the classroom or at home, through collaboration and exchange of classroom pedagogical experiences [74, 99]. For example, the theory helped

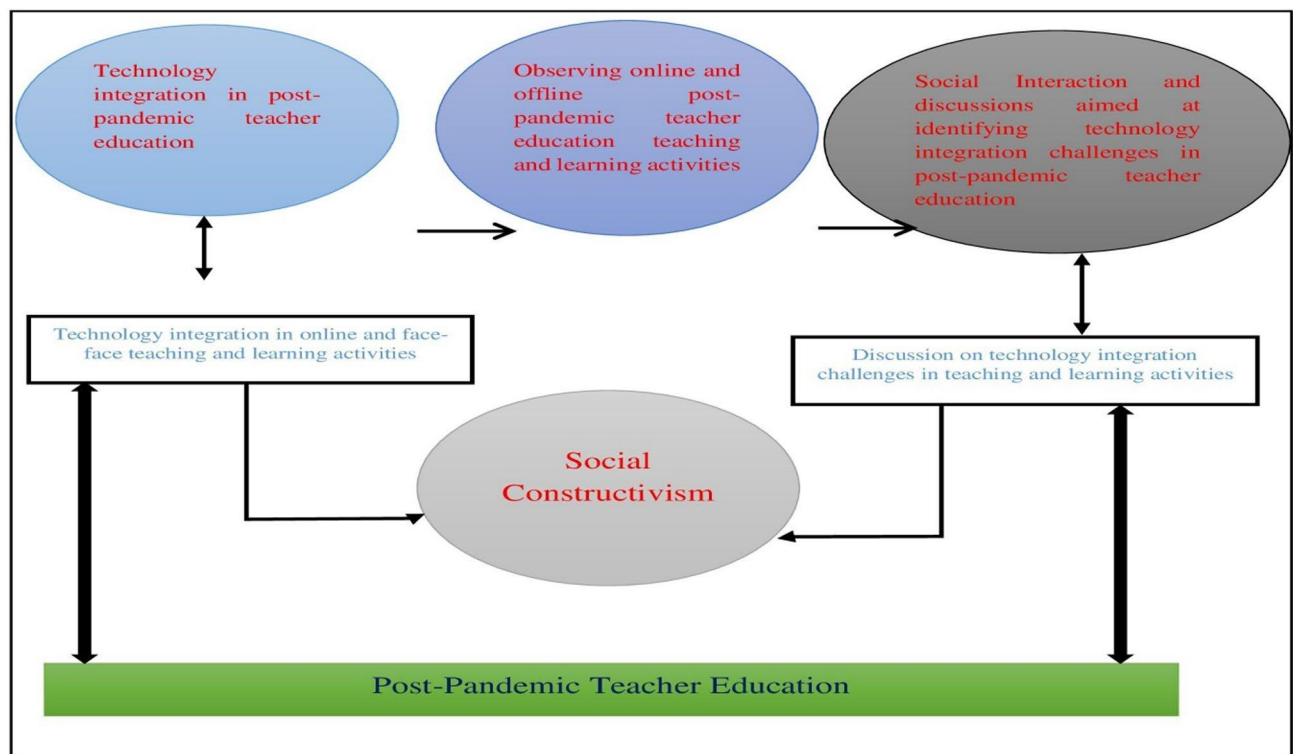


Fig. 1 Social constructivism theory as applied in the study. Adapted and modified from [84]

us understand both the barriers and the solutions to technology integration in post-pandemic teacher education and enabled us to share observed challenges with educators in a purposefully interactive environment.

Furthermore, the theory facilitated a collaborative analysis of the technology integration challenges in post-pandemic teacher education, with the active participation of our esteemed audience. [35, 61, 73] all argue that social constructivist theory provides a platform for understanding the importance of personal and collaborative learning environments in overcoming technology integration challenges. In line with the viewpoint of the authors of this study [95], emphasised that social constructivism aids in the development of knowledge based on individual experiences and perspectives. We maintain that social interaction has a significant potential for mutual influence on knowledge development, a process in which our audience plays a crucial role.

This study's use of social constructivist theory directed our belief that social interactions permit discussions and the sharing of knowledge and experiences of technology integration in instructional practices among teacher educators. We argue that this leads to knowledge co-development on identifying and mitigating the challenges that technology presents in post-pandemic teacher education [8, 72, 78]. Applying the social constructivism theory's components (social interaction and tools) promoted fruitful conversations among educators about the challenges associated with technology integration. The two also helped develop knowledge of potential preventive measures for eliminating those challenges in post-pandemic teacher education in South Africa.

Furthermore, we argue that the inclusion of a tool such as technology in this study provided educators with a diverse range of post-pandemic instructional strategies that fostered student knowledge development and collaborative learning experiences. In support of our argument [3], suggests that using a tool like technology in the post-pandemic era can enhance and make classroom learning engaging, collaborative, and intuitive for students. The argument presented in [3] aligns with the concept discussed in [92] about knowledge construction in the classroom through a cultural tool like technology. We also add that, as the post-pandemic teaching and learning process currently demonstrates, integrating technology into classroom instruction has helped educators achieve their primary teaching objective, which is to ensure efficiency in lesson activities.

Expanding on the conversation about the usefulness of a cultural tool (technology) in this study, we argue that increased technology use in the post-pandemic era of teacher education has raised and continues to raise awareness of the importance of modern teaching technologies as well as their influence on learning abilities [59, 69, 73]. Accordingly,

[42, 79] contend that incorporating contemporary technology into instruction led to improved learning outcomes, best practices, and the exposure of unsaid or spoken concerns regarding the use of technology in the classroom. [42, 73] assert that understanding and benefiting from pedagogical practices involving technology in teaching is essential to identifying and resolving spoken or unspoken issues related to the use of technology in teacher education and learning activities.

In summary, we utilised the [92] ideology to explore the use of cultural tools, with technology playing a supportive role. By incorporating this theory into our research, we were able to recognise existing and potential technological challenges that educators and pre-service teachers might encounter or generate. This theory helped gather insights on addressing these obstacles and enhanced our understanding of the approaches educators employ to surmount them in post-pandemic teacher education.

1.3 Methodology

This study investigated the challenges and adaptations associated with technology use in post-pandemic teacher education using a qualitative exploratory case study approach [9]. The single case in the study involved educators training pre-service teachers in an education faculty's teacher education department. In addition, the researchers employed the qualitative exploratory case study approach to gather inductive and qualitative evidence (data evolved from the participants) that explains and yields new understandings of the topic. In this way, the data collected answered the research question and contributed to a comprehensive understanding of the phenomenon in post-pandemic teacher education. Furthermore, the researchers' observation notes and educators' (participants) experiences with the challenges of technology adaptations during lesson activities led to a thorough understanding of the phenomenon under study.

However, the researchers observed the participants' classroom teaching as insiders. Being an insider implies that the researcher adopts the participant role, actively observing and gaining insights through the investigative process [30, 81]. The research spanned four semesters, from 2021 to 2022. We must also clarify that the Bachelor of Education (Bed) programme, i.e., Grades R–3, was designed to prepare pre-service teachers to teach in the foundation phase. The programme aims to equip pre-service teachers with teaching and content knowledge and develop future teachers' competence, critical thinking, creativity, and care for children in foundation phase classes. Technology integration in lesson planning and assessment is optional in this programme. Six university educators ($n = 6$) were purposefully selected for the study.

These educators were chosen based on the following criteria:

- Participants must be teaching foundation-phase pre-service teachers' instruction in the education faculty.
- must be willing to incorporate technology into instructional processes and
- must participate in the research activities.

Figure 2 displays the participants' coded identities and the lessons taught in the Bed Foundation phase programme.

The participants' teaching specialisations included mathematics, art education, academic literacy, instruction in English and microteaching, teaching practice lessons, and research. Each participant's identity was coded as TE1, TE2, TE3, TE4, TE5, TE6, and TE7. However, due to personal and academic obligations, TE6 was excluded from the study [82].

Our data collection process was comprehensive, involving non-participatory classroom observation and focus-group interview sessions. These methods were instrumental in gathering qualitative data that answered the research question. We chose the non-participatory observation method to gather first-hand information from the participants on the subject matter under study [18]. We observed the participants as they taught in the classroom, both online and offline,

Fig. 2 Analysis of participant's teaching specialisations. Curled from [84]

Participant	Topics Taught/Observed
TE1	Instructing in English (First Additional Language) and Microteaching
TE2	Research (Action research)
TE3	Academic Literacy (Referencing)
TE4	Mathematics (number sense)
TE5	Teaching Practice Lessons
TE 7	Art Education (Creativity in foundation phase classes)

Table 1 Snippet of the study's observation guide

Question	Notes
Difficulty/challenges of integrating technology to teach content (state clearly)	
Briefly write any new occurrence observed in the teaching	

Table 2 Description of classroom observations

Course/discipline	Topic	Number of classroom observations	Hours used observing the topics taught
Mathematics	Number Sense	3	2
Professional Education Studies	Teaching Practice Resources	3	2
English First Language	Giving Instructions in English Microteaching (Online and Offline Classes)	3	2
Academic Literacy	APA Referencing	3	2
Art Education	Creativity in Foundation Class	3	2
Research	Action Research	3	2

to understand the technological obstacles faced by pre-service teachers and teacher educators during the teaching and learning process.

As non-participants, we, the researchers, interchangeably observed technology integration in the participant educators' classroom teaching. This was necessary to produce notes for discussion with the participants so they could collectively identify, critique, and document methods of alleviating the challenges of technology utilisation in higher education. To gather data, we used the observational notes developed by all of the researchers. Snippets of the observation guide are shown in Table 1 below.

In addition, Table 2 gives a description of the classes interchangeably observed by the researchers.

In all the classes observed, the participant teacher educators informed the pre-service teachers of the researcher's presence. The pre-service teachers were in years 1, 2, 3 and four of the foundation phase Bed programme. In addition, the participants educated the students about the research focus and what the researchers intended to do with the research findings. In all, a total of 18 classes were observed over four semesters from year 2021 to 2022. Before using the observation guide, the researchers often met to discuss and critique the use of the guide and to ascertain that it met the purpose of the research. These notes were closely examined, discussed, and integrated into a document during researchers' meetings.

Furthermore, the researchers fostered a collaborative environment by using a focus-group interview session to discuss the research outcomes, based on observation notes, with the participants. This approach provided an opportunity for the participants to contribute to or critique the data that had emerged from the study. Before the agreed interview date, the researcher sent each participant an electronic copy of the interview questions to allow them to familiarise themselves with the questions. This step was crucial in helping the teacher educators prepare their answers or make necessary suggestions or amendments to the questions. The participants signed the consent forms and were assured their responses would be used solely for research, maintaining the rules of confidentiality, anonymity, and credibility throughout the research process.

Most importantly, using focus group interview sessions in this study resonates with the [17] stipulation that interviews should be conducted to gather the kind of data that would triangulate the findings from other instruments used in a study, thus increasing the reliability of the findings. The agreed intention was for the data gathered through the focus group interview session to be triangulated with the findings gathered through non-participatory observation.

As a result of these, both the researchers and the participants were able to identify the different technological challenges experienced, especially those experienced by teacher educators and those experienced or introduced by the pre-service teachers. Questions such as (1) explain some of the challenges encountered during teaching; and (2) how was this challenge overcome? Were included in the focus-group interview questions guide. At the end of the session, the participants collectively updated their knowledge on the challenges of technology they encountered. The focus group interview session was held at the end of the teaching engagements in a conference room in the Faculty of Education and was of two hours duration. Before the interview, the researchers sought the participants' consent to record

the interview session. One of the researchers recorded the interviews using a tape recorder, while the other researchers made notes during the session.

The data from the observation guide and interview recording were meticulously analysed. For instance, a qualitative and thematic analysis was conducted on the notes found in the observation guide. After carefully reviewing the notes to identify the different technological challenges experienced by teacher educators and those experienced or introduced by the pre-service teachers, we used Microsoft Word to present the notes as a text. Later, Microsoft Word was also used to turn the information from the interview recordings into text to show the different technological challenges. Based on participant responses to the research question, the NVivo software was then used to analyse both texts to identify themes and sub-themes that addressed the research question. This thorough analysis process ensures the reliability and validity of our research findings.

After the analysis, the participants were granted access to the data to show who had said what and why. This was done to accommodate and augment information missed during the focus-group interview session. It's important to note that, as mentioned earlier, the coding of participants' identities was done by a researcher, labelled as TE1, TE2, TE3, TE4, TE5 and TE7. The researchers received ethical clearance from the Education Faculty Ethics Committee before commencing the study. Throughout the study, no participant was coerced into participating, and no one was prevented from opting out should the need arise. These ethical considerations were adhered to at every stage of the research, ensuring the integrity and credibility of our findings.

During the analysis of data gathered, instances where the observation notes and respondents' responses indicated socioeconomic status, load-shedding, plagiarism, and technology incompatibility as challenges, four themes were coded as "Ad-hoc Solutions in mitigating the impact of socioeconomic issues", "Adapting teaching strategies during load shedding", "Addressing device incompatibility", and "Plagiarised Solutions", respectively. Table 3 provides the code snippet of themes generated during the data analysis.

1.4 Findings

The findings gathered answered the research question: What technology integration challenges are experienced by a group of university educators and pre-service teachers in a post-pandemic teacher education programme? The following sections cover the challenges and suggestions for solutions put forward by the participants as answers to the research question:

1.5 Ad-hoc solutions in mitigating the impact of socioeconomic issues

During the focus group interview, the participants engaged in social interactions, in line with [92] ideologies, to collectively recognize that effective technology integration in post-pandemic teacher education requires considering the socioeconomic status of pre-service teachers. The focus group interviewees' collective knowledge and personal experiences proved helpful in pinpointing the presence of certain pre-service teachers from low-income backgrounds in the classroom.

Unpacking the data, TE1 discussion during the focus-group interview session and our observation notes revealed that some students required assistance accessing an Internet-enabled laptop to participate in online learning and to gain access to learning materials in a traditional classroom setting. During the focus group interview session, TE1 suggested: I advised them to come to campus to use the computers in the computer room in the department.

TE1 explained that this approach could help solve the technology-access challenges faced by students who cannot afford to buy their own devices. According to TE1, *"this approach could enable students to pursue their education without the additional financial burden of owning the required equipment."*

In agreement with TE1's advice, TE4 acknowledged that:

It has also come to my notice that some students need mobile phones and laptops, meaning they cannot afford to buy a laptop to support learning.

In her advice, she appealed to her colleagues:

Let us talk to colleagues who can afford to give students their spare phones to encourage them to perform well in their courses.

After these interview sessions, we observed, in TE4 and TE2 classes, that TE1 and TE2's advice was later used in an online national Mathematics examination for year two and three students.

Table 3 Themes generated during data analysis

Theme	Description	Example
Ad-hoc solutions in mitigating the impact of socio-economic issues	Inequality in the usage of technology in the classroom between pre-service teachers from high- and low-income households	"It has also come to my notice that some students need mobile phones and laptops, meaning they cannot afford to buy a laptop to support learning. Let us talk to colleagues who can afford to give students their spare phones to encourage them to perform well in their courses."
Adapting teaching strategies during load shedding	Sudden interruption or intermittent rotation of power	"TE4, TE7 and pre-service teachers had backup plans for power outages in their teaching and learning situations"
Plagiarised solutions	Pre-service teachers used technology to solve academic tasks without acknowledgement	"In some of the assignments submitted by the students, the rate at which students plagiarise work from the Internet is alarming"
Addressing device incompatibility	Situated technologies not read by educators' teaching devices	"The incompatibility of projectors with my laptop has already shifted my interest in looking for a technology to use in the classroom, causing me unhappiness and dissatisfaction most of the time"

The teacher educators loaned their laptops to some students to use during the examination. These findings resonate with [101], who claim that, to address the socioeconomic gap in teaching, institutions need to provide resources or technologies in schools for students whose parents' incomes are low. This action could help improve academic performance and equality in learning. The approach suggested by [101] may not be sustainable and would depend on the goodwill of confident university educators and students' disposal toward accepting technological assistance during instructional activities. However, we reason that personal devices may not be protected by the same security measures as those at institutions, potentially exposing university educators and students to possible breaches and misuse.

As argued by [7, 22], a further implication of this approach is the over-reliance on such ad-hoc solutions, potentially delaying the development of more equitable and sustainable institutional policies. However, the focus-group interview session among educators on these critical issues and data generated through observation notes enabled all participants to share their technological pedagogical experiences. This was done in a way that allowed knowledge about the contradictions, inconsistencies, and inequalities in the use of technology in classroom teaching to be discussed, shared, absorbed, and reused to enact and support inclusive classrooms.

Furthermore [10, 39], argue that, through a community-based discussion and implementation of technology integration in higher education, students may be open to interacting and building subject matter knowledge on an equal footing while at the same time providing teacher educators with an opportunity to meet and discuss how to understand and develop knowledge through the use of cultural tools like technology while also mitigating the obstacles that technology introduces into teacher education. The arguments presented by [10, 39] support [101] arguments on mitigating the challenges which arise from students' low economic status in post-pandemic teacher education's technology integration instructional practices.

As part of the ad-hoc solutions to lessening the effects of socioeconomic problems, we argue that educators need to be sensitive toward pre-service teachers from low-income backgrounds who do not have access to the kind of technology that can be used to enhance classroom instruction. We agree with TE4's suggestion on the leasing of devices to students. In support of this idea, we argue that teacher educators could discuss with students in the classrooms to identify the ones needing support before lending out their Internet-enabled gadgets or bringing into their classrooms those belonging to their colleagues who are not using them during that teaching time. This collaborative approach ensures that everyone is part of the solution. Even though we acknowledge that, as [92] suggested, equitable learning opportunities can be achieved in teacher education to demonstrate knowledge co-development through collaborative and interactive learning methods and mediums like technology.

However, we reason that, while students are using borrowed laptops, there is a possibility that they could gain instant access to teacher educators' private information. Teacher educators must observe their students in the classroom, engage with them, and collect the laptops back as soon as the lesson is completed to prevent students from having access to teacher educators' personal information and documents.

1.6 Adapting teaching strategies during load shedding

Adding to the discussion on technology integration challenges experienced by university educators and pre-service teachers in a post-pandemic teacher education programme, the findings revealed load shedding to be another problem encountered in post-pandemic teacher education. In the focus group interview, every participant reiterated and contextualized this difficulty in society and education. We also observed how load-shedding affected lessons in the classroom. For instance, we observed that a smaller proportion of pre-service teachers without laptops left the classroom when the electricity went out and that several pre-service teachers promptly turned down their laptops.

In South Africa, the state-owned enterprise known as Eskom imposes load-shedding or rolling blackouts by cutting electricity distribution for 2–4 h throughout particular areas. Load-shedding affects businesses, educational institutions, and households. Teacher educators (TE1 and TE7) reported adapting and diversifying their teaching and learning methods in response to this challenge, demonstrating their resilience and adaptability. For instance, TE7 commented:

I have always had to have a contingency plan for power, which may fail at any time.

Confirming TE7's comment on power failure caused by load-shedding, TE1 indicated that she has to "*study the daily newsletters on load shedding to know when to work on my laptop.*" Agreeing with the TE1, [85] argued that electrical power interruptions due to continual load shedding and blackouts remained one of the challenges of technology integration in South Africa-based higher education. Likewise, [12] identified load shedding in South Africa as a challenge to technology incorporation in learning institutions immediately after recovery from the COVID-19 pandemic and their resuming teaching programmes.

From the discussions, we argue the need to adopt multiple learning modalities in response to unexpected technological disruptions. Our argument aligns with TE7's decision and capacity to adopt pedagogical flexibility in response to power outages. In addition to power outages, TE7 planned for such disruptions to minimise the negative impact of power outages and ensure meaningful and uninterrupted classroom teaching. In the same lane, TE7 opined that pre-service teachers should be open to discussion to understand their power predicament and to come to an agreement that can allow them to "*bring their own powered devices to the classroom to support learning*".

We argue that, in situations where some students lack access to a cultural tool like technology, as previously mentioned, equitable measures must be implemented to ensure that pre-service teachers share, learn, and socially interact [92] using accessible devices for learning [1]. Although pre-service teachers are encouraged to bring their own devices to the classroom in higher institutions of learning in South Africa, we contend that an additional measure would be the provision of a stand-by source of electricity, such as a generator or green energy sources to assist in powering teaching and learning devices and to enable uninterrupted use of teaching and learning technological aids when ESKOM interrupts power supply.

1.7 Addressing device incompatibility

In response to the research question: what challenges do university educators experience in post-pandemic teacher education? Our interaction with the participants during the focus group interview session and interchanged classroom observation played a crucial role in understanding the disappointment and frustrations in participants' various classrooms over the incompatibility of hi-flex data projectors and speakers with their laptops.

TE1, for instance, expressed her disappointment by stating that:

The incompatibility of projectors with my laptop has already shifted my interest in looking for a technology to use in the classroom, causing me unhappiness and dissatisfaction most of the time.

Furthermore, in our interactions with the participants and classroom observations, we noted that they experienced difficulty connecting their devices with some technologies (Wireless data projectors and speakers) in the lecture rooms. We observed that some pre-service teachers in the classroom or lecture room lost focus on learning activities when educators experienced connection challenges.

Instead of focusing on the lessons, some pre-service teachers began to read messages on their phones, make calls, or excuse themselves to address personal responsibilities before returning to class. We infer that the issue of technology incompatibility resulted in instructional time wastage and diversions both for teacher educators and pre-service teachers. When two devices are not compatible, they cannot communicate with one another [51]. According to [31] and [43], teacher educators experience challenges when incorporating modern technology into their mentoring and teaching practices because of technology incompatibility-related challenges.

The findings suggest that the persistence of incompatibility-related challenges in teacher education could lead to system failure. As a result, incompatibility-related challenges could discourage educators from integrating technology into their classroom teaching. To address the concern over technology incompatibility, TE4 proposed that:

The university's administrators should find solutions to projector incompatibility with our laptops to encourage us to continue teaching effectively in the classroom.

Another approach to solving the problem of technology incompatibility in teaching is noted by [13] and [28]. Byukusenge et al. and Fang et al. [13] and [28] suggested that a community-of-practice collaboration approach could help develop and expand educators', pre-service and in-service teachers' technical skills and knowledge of technology teaching. Furthermore, we contend that to find technology experts who can work with teacher educators and pre-service teachers in the classroom, a more hands-on approach and community of practice interactions are required to identify who can provide technical assistance on "what" technology and "when" and "how" to integrate the technology into classroom instructional plans. To make up for these in post-pandemic teacher education, on-site technical training, support, and community-of-practice interactions are required for technological expertise for effective post-pandemic teacher education.

1.8 Plagiarised solutions

Before the focus-group interview session, we noticed that the participants assigned homework to the students and anticipated that they would provide accurate responses to questions posted online. The findings also showed that, in response to

the research question, focus group interviewees talked about and recognized assigning homework to students, assuming that answers would be submitted online (university's LMS). This approach to assignment submission caused some pre-service teachers to become disgruntled and download/plagiarise internet solutions without crediting the original writers.

Further strengthening the discussion was TE4's comment during the focus group interview session:

In some of the assignments submitted by the students, the rate at which students plagiarise work from the Internet is alarming.

We describe plagiarism as using knowledge and ideas in a published or unpublished article without consent or acknowledgement. In agreement with our description of plagiarism, and based on their findings, [88] argue that plagiarism persists in higher education as some students use information in published or unpublished articles or books and present it as their knowledge without acknowledging the authors.

Providing evidence for plagiarism in the findings of the current study, TE7 added:

I noticed that some students logged in to Google and copied from other sources, word for word, without their input and citations, and submitted.

These findings resonate with a study conducted by [76] on increased instances of plagiarism during and after the pandemic. They reported that most students copied and pasted information into their writing to create easy shortcuts to the assignment submission. While a concern, this behaviour also reflects the challenges students face in managing their workload. Similarly [76], reports that university students, due to ease of access to the Internet, copied and pasted work to fulfil their assignment submission requirements. In addition [64], identified one of the consequences of plagiarism: students become less disciplined and inconsistent in completing their assignments, a situation that we, as educators, should strive to prevent. Nusi et al. [64] identified an overload of assigned tasks in each course as another reason for students' plagiarising solutions to assignments.

Furthermore, we argue that the absence of direct and developmental supervision in teacher education causes pre-service teachers to resort to plagiarism as a solution. To address the issue, [64] advocates that lecturers should reduce the number of assignments given to students to avoid plagiarism and should offer regular feedback on the assignments.

Providing solutions to the persisting high level of plagiarism in teacher education and technology integration challenges experienced in post-pandemic teacher education, TE4 advised:

Let us tell the students to avoid plagiarism and cite appropriately to avoid the consequences afterwards.

Supporting, in a concrete way, TE4's advice on a measure to curb high plagiarised solutions in teacher education, TE7 recalled the proactive measure taken in her lesson:

.... I now link assignment submission to Turnitin. Whenever students wish to submit an assignment online, they must use Turnitin to check for plagiarism....

The findings and discussions show that if pre-service teachers are educated and interacted with on the moral implications of submitting well-referenced assignments, honest outputs, and subject-matter competence, they may become more straightforward and honest in teacher training. Through conversations with pre-service teachers, teacher educators should provide practical instances concerning identifying relevant articles online and extracting information from these sources while citing the sources correctly. We opine that educators, in collaboration with university-based educational technologists, demonstrate plagiarism detection software with pre-service teachers to discover similarities between the prepared document and other online sources of information. Likewise, engagement and communication regarding plagiarism between teacher educators and pre-service teachers could help engage in group and individual interactions. The interaction could aid in acquiring and developing knowledge regarding correct citation and acknowledgement in the assignment submitted online.

2 Discussion, implications, and recommendations

As a cultural tool, technology has become so ingrained into society and teacher education for daily survival [19, 44]. According to [3], cultural tools such as technology are essential for any society or parastatal to progress and achieve notable achievements. Teacher education now strives to enhance subject matter understanding and technological proficiency through cultural tools like technology [3].

However, social interactions with and among the participants through the focus-group interview session gave rise to a sufficient understanding of the difficulties associated with adapting a cultural tool like technology in post-pandemic teacher education. The results support [92] theory that social interaction and cultural tools like technology can foster collective knowledge development in a learning space. As can be seen from the results, participant

responses and interchanged classroom observations were used to understand experiences with technology-based instruction and the difficulties faced in the era of post-pandemic teacher education.

Additionally, the results indicate that most of the participants discussed their personal experiences and the difficulties faced by pre-service teachers when it came to technological pedagogy in the classroom. It appeared from the responses given by the participants that they are aware of and prepared to mitigate any form of digital divide in their classroom teaching contexts. As a result, by employing last-minute fixes and practically focused solutions, they created and introduced a stopgap solution to problems with technology access and unethical use in the learning process.

The findings confirmed that certain pre-service teachers do not have access to technology because of their poor socioeconomic status, which advances the discussion around technology access. This specific challenge draws attention to the persistent socioeconomic and digital disparities that affect the use of technology in post-pandemic teacher education in South African higher education institutions.

We deduce from our findings that there is a disparity in pre-service teachers' economic situations concerning the use of technology in post-pandemic teacher education. Aligning with this finding [84, 86], make a case for teacher educators to interact socially with students and colleagues to address the lack of access to personal devices for at-home or in-class use among students from low-income homes. We concur with the position of [86] by arguing that, through such engagements, teacher educators could develop the knowledge and competency required to use a cultural tool like technology and an interactive teaching method in ways that make learning both inclusive and equitable in teacher education.

While we acknowledge that lecture halls and seminar rooms are equipped with contemporary technology, continuous learning after classroom engagement still needs to be improved for pre-service teachers from low-income homes [26]. We contend that to implement inclusive teaching with accessible tools like technology in post-pandemic teacher education, educators need to evaluate and accommodate the learning needs of pre-service teachers in instructional plans [6]. By learning about the learning needs of pre-service teachers, the participants show empathy and assist low-income pre-service teachers with access to technology for learning purposes. [21, 26] argue that educators engaging and showing empathy for pre-service teachers from low-income homes signals the need for educators to encourage students to become more resilient and creative in designing solutions to the challenges of technology use in future classrooms.

In addition, the findings showed that South Africa's unpredictable power outages influence pedagogical plans and classroom implementation. [11, 57] argue that technology will be successfully integrated into post-pandemic teaching and learning if consistent and reliable electricity power is guaranteed. We also agree that electricity supply is critical to powering any technologies considered supportive in IT (information technology)-related classroom learning activities. We, however, recommend backup power to continue teaching and learning in the face of electricity disruptions. Supporting our argument and recommendation, but with a caveat [12, 85], caution that a shortfall of electricity may affect technology integration in teacher education, and such perceptions may lead to diminishing use of technology in the teaching and learning process.

Another solution to frequent and unpredictable power outages is suggested by [46], who advocates for educators to discuss with other educators and pre-service teachers, increasing knowledge of power assessment and knowing when to encounter and deal with load shedding on campus or residences. Regular updating of knowledge of power outage schedules could assist in lesson/lecture planning and the designing of tasks in time before the power is interrupted. The findings also point to the reality of setting a platform for educators and pre-service teachers to exchange knowledge on load-shedding schedules and methods of carrying on teaching or learning during power outages. It would be helpful for educators to think about establishing a vibrant and supportive online practice community for students to know how and when to implement instructions [68].

After reviewing the results, we contend that educators need to be supported to mitigate the challenges of technology incompatibility in instructional practices. Ochieng and Katende [66] advised that stakeholders in tertiary institutions must collaborate with educators and pre-service teachers to navigate the evolving landscape of technological challenges in higher education. In this context, the findings reveal the mismatch between the features and configurations of a hi-flex wireless data projector and Bluetooth-enhanced speakers and the configuration and operating system of teacher educators' laptops. This suggests an urgent need for policymakers and teacher educators to reassess technology integration in teacher education.

In their endorsement of the need for technology integration reassessment [40], contend that teacher educators had teacher training when technology was not compulsorily used in training. Given that the findings of our study resonate with those of [40], most educators may have yet to address technology integration in their initial teacher training. They may not have attended professional development courses on specific technologies that could support their teaching.

Thus, they require technical training and support to develop and update the knowledge necessary to identify possible errors and apply a workable solution in their classroom. Training using newly introduced contemporary technology must be faculty-based to allow individual educator critique, group discussion, and demonstration and development of the knowledge required to incorporate modern technology in instructional plans effectively.

Supporting our argument, we reason that, in the absence of technical training, educators or teachers become frustrated, resulting in an unwillingness to use technology, and they become discouraged from further adopting and integrating technology in their classrooms. Expanding our content, we assert that the provision of technical training by policymakers has the potential to facilitate step-by-step guidance in complex problem-solving practices in teaching practices. In addition, we argue that, through the provision of technical training, both policymakers and teacher educators would become knowledgeable about the kinds of technology they would need, which would be appropriate to their instructional plans. Based on a collective understanding, policymakers may make informed and corrective decisions about the technologies useful for instructional practices in teacher education. We recommended that training provide firsthand learning-to-teach opportunities in ways that will assist in ensuring sustainable technology integration in education in the period of teaching uncertainties.

We add that the provision of training activities in the use of modern technologies in instructional practices has the potential to embody or assist in exemplifying [92] social constructivist learning theory. This theory, applied to the present teaching and learning situation requiring the integration of technology, can be said to develop the idea that a collaborative learning environment, in which educators and pre-service teachers engage in active discussion, can lead towards their acquisition of the kind of technological support, skills and experiences necessary for pedagogical interventions that can mitigate the modern technology integration challenges present in post-pandemic teacher education. We further argue that, through ongoing technical training and support, teacher educators and students could recognise the advantages and shortcomings of technology utilisation in post-pandemic professional development.

Furthermore, the findings also revealed a steep plagiarism increase in assignments submitted by pre-service teachers. Relating to [92] ideologies on the use of cultural tools for knowledge development, we argue that while technology, a tool widely used for learning in post-pandemic teacher education, will continue to be a tool for mediating knowledge, it currently provides pre-service teachers with access to a vast array of information that post-pandemic pre-service teachers can download and use but not without acknowledging the legitimate owners of the resources [37, 38]. Pre-service teachers must be advised against using technology to cheat on assignments or use information without acknowledging the authors.

We also contend that if this issue is not resolved by policymakers and teacher educators in the teacher preparation process, it may lead to students' lack of interest in reading, writing, and research, as well as a possible increase in pre-service teachers using technology in an unethical manner, which may in turn impact on their future classroom and societal experiences and contributions. In addition to these provisos, it may be pertinent to predict that the continuous influx of technology into society and social communication might escalate plagiarism in teacher education [100].

These results highlight the urgency of taking immediate action to safeguard moral principles and training requirements in teacher education and society. Further research is necessary to involve teacher educators and their students in interactive technology integration sessions to gain insight into different perspectives on the difficulties associated with integrating technology into post-pandemic teacher education to open opportunities for potential solutions to the problems. The teacher preparation programme must establish a think tank to examine the contemporary issues raised by the study and potentially put the solutions chosen by the study's participants into practice.

Establishing a think tank could create a forum for pre-service teachers and teacher educators to discuss the various technological barriers to post-pandemic teacher education. This suggestion is advantageous for teacher education programmes, as it can foster a sense of community, spark creativity, and enable participants to engage, exchange personal stories, and jointly acquire subject-matter knowledge.

3 Conclusion, limitations, and suggestions for future research direction

The COVID-19 lockdown significantly increased the importance of technology in teacher education, making technology use a crucial element in learning plans and instructional strategies. Nonetheless, the findings in this study point to several challenges pre-service teachers and teacher educators face when adapting technology into post-pandemic teaching or learning activities. One way to eradicate difficulties such as incompatibility challenges, unethical use of technology and

lack of access to technology in post-pandemic teacher education programmes could be through technology integration engagements between policymakers, educators, and pre-service teachers.

Therefore, we strongly advocate for knowledge development through social engagements that discuss the benefits and drawbacks of a cultural tool like technology in post-pandemic teacher education. We believe that such social engagements can foster dialogue and knowledge sharing between teacher educators and pre-service teachers, or among educators. This dialogue, we argue, can help to realize ideologies on knowledge co-development through social interaction and cultural tools like technology.

However, we acknowledge that this study's limitations could affect the reliability and generalizability of the findings. These findings are inevitably subjective and, to a lesser or greater extent, dependent on the opinions of the participants (educators), which may not match the views of educators in teacher training institutions elsewhere. Significantly, the findings of this study emerged from a small sample size of educators, all females. However, we noted that gender effects could be present in the findings. Therefore, it is inappropriate to interpret the findings of this study as representative of all teacher educators in South Africa or around the world.

In conclusion, in order to generalize the study's findings on technology adaptation and challenges in post-pandemic teacher education, we recommend revisiting the topic in one or all of South Africa's education provinces. This could be done using larger educator sample sizes and either the same or newer research methodologies.

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Author contributions Adedayo Olayinka Theodorio (PhD) initiated research process, discussions, reviewed and analysed the data and wrote the manuscript Zayd Waghid (PhD) contributed by joining in research discussions, examined the data and reviewed the whole article Andrew Wambua (PhD) joined in reviewing, analyzing and discussing the structure of the article.

Data availability The data used in this study is the data gathered on the challenges and adaptations associated with technology integration in post-pandemic teacher education. The data analysed included viewpoints from educators preparing pre-service teachers in a university's teacher education department located in South Africa's Eastern Cape Province. Scholars and non-scholars may reasonably seek access to the data from the corresponding author for non-profit academic research reasons.

Declarations

Ethics approval and consent to participate Ethical clearance for this work was sought and granted by the institution's Education Faculty Research Ethics Committee (EF-REC). The study complied with EF-REC regulations on informed consent and research participation with participants and the research guidelines of the research University.

Informed consent As mandated by the research standards and regulations of the EF-REC, all participants consented to participate in the study without coercion.

Competing interests The authors declare no competing interests.

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