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Research Paper

Collaborative Virtual Environments (CVEs) in the Preparation of Pre-Service Mathematics Teachers

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ABSTRACT

In recent times, teacher preparation programmes have faced significant challenges as many universities transitioned to fully online or hybrid instructional models as a result of the COVID-19 pandemic outbreak. These sudden shifts drastically decreased classroom teaching opportunities, which was a cornerstone of teacher preparation programmes to help preservice teachers learn how to teach effectively. Therefore, considering the importance of visualizations in mathematics education for facilitating teaching, motivating students, and satisfying their desire to comprehend abstract mathematical concepts, this study investigates the barriers to utilizing, and the effective ways of integrating Collaborative Virtual Environments (CVEs) in the preparation of pre-service mathematics teachers. Underpinned by an interpretivist paradigm, the study employed a qualitative research approach and a case study design. Data were collected from twenty-five pre-service mathematics teachers, two mathematics teacher educators, and one department head. For this study, data collected were analysed using thematic analysis, and data trustworthiness was ensured through triangulation of the unit of analysis. Research findings revealed that the use of CVEs in teacher education programs is hampered by several factors, which include resistance to change, technological limits, costs and time constraints, assessment difficulties, equality and access issues, and a lack of training and support. Furthermore, the findings highlighted that for CVEs to be effective in teacher preparation programmes, mathematics educators should encourage the simulation of classroom scenarios, facilitate group discussions and cooperative learning and participate in virtual professional development opportunities.

INTRODUCTION

In today's society, learning is a permanent trait that can be developed in both formal and informal settings. However, not all students possess the abilities required for independent study. Therefore, both formal and informal instructional settings need to encourage the growth of these abilities so that students can acquire the required knowledge. This is because self-regulated learning, self-evaluation, and activities to change study habits encourage students to actively and critically participate in decisions affecting their education, which will create meaningful environments (CaberoAlmenara, 2013). In recent times, educational methods have expanded steadily as the use of information and communication technology (ICT) has increased. Due to its usage in education, some new terminology for pedagogical methods has emerged (Dhakal & Sharma, 2016), and these recently popularised terms include MOOC, SOOC, M-learning, o-learning, blended learning, hybrid learning, e-learning, and others (Johannesen, Øgrim, Pangeni, & Dhakal, 2016; Mncube, Olawale, & Bitso, 2021). Studies have shown that these techniques are beneficial for improving learning outcomes in the following areas: accessibility, quality, interactive, meaningful and contextual learning, and dynamic and enjoyable learning (Khanal, 2014; Dhakal & Sharma, 2016; Navarro-Ibarra, Salazar, García, & Leyva, 2017). Therefore, formal educational institutions today are under increasing pressure to comprehend, react to, and adapt to this rapidly advancing technological innovation in their educational services and practices (Dhakal & Sharma, 2016), especially in the post-COVID-19 pandemic era.

According to Navarro-Ibarra et al. (2017), virtual learning is a method of reassembling knowledge on a personal level that is based on the cognitive structure of learning. Basic cognitive abilities, particular knowledge of a subject, learning techniques, metacognitive skills and self-regulation, affective and motivational aspects, goals and expectations, and learning strategies are some of the components that make up the virtual learning framework (Navarro-Ibarra, Salazar, García, & Leyva, 2017). Each of these components, along with the students' use of them, can result in high-quality learning (Khanal, 2014; Johannesen, Øgrim, Pangeni, & Dhakal, 2016). Franklin and Harrington (2019) claim that virtual learning is a method of imparting knowledge to students that explicitly makes use of software, the Internet, or both. This lessens or eliminates the need for teachers and students to share a classroom (Franklin & Harrington, 2019; Wei & Chou, 2020; Taylor, Dewsbury, & Brame, 2022). This is because when teaching is done virtually, it is done online, and even though the teacher is not physically present with the students, the teacher gives instructions (Shudayfat & Alsalhi, 2023).

However, one of the difficulties teachers encounter when teaching mathematics and other related science subjects is the students' comprehension of mathematical and scientific concepts. This is attributed to traditional education, which is relatively lengthy (Shudayfat & Alsalhi, 2023), and relies on dictation and memorisation rather than connecting knowledge and solving issues (Olawale, 2021; Olawale, 2022). As such, traditional education demonstrated a deficit in effectively transmitting knowledge (Mokhtar, 2016). However, numerous pieces of research highlight contemporary learning techniques using modeling or simulation in online learning environments (deNoyelles & Seo, 2012). This simulation uses 3D visuals and is either textual or graphic, all of which assist students in creating a collaborative learning environment, learning concepts that can help them master competencies and providing opportunities for students without being restricted to time and place, as well as providing the link between reality and knowledge (Hearrington, 2010; Alharbi, Platt, & Al-Bayatti, 2013; Alves, Miranda, & Morais, 2017; Pem, Dorji, Tshering, & Dorji, 2021). While it is also believed that in mathematics education, visualisations are still used whenever possible to support teaching, inspire students and feed their need to see abstract mathematical facts, it becomes important to investigate the factors that impede the use of Collaborative Virtual Environments (CVEs) in the preparation of pre-service mathematics teachers, and how CVEs can be effectively integrated into teacher education programmes.

Technology Integration in Mathematics Teacher Education Programme

Teacher education programmes, like nearly every other sector or profession, have struggled with the rapidly changing societal reliance on domain-specific technology, as well as the requirement for educational programmes and practitioners to adapt to those technologies (Foulger, Graziano, Schmidt-Crawford, & Slykhuis, 2017). This has exacerbated tensions in how teachers undertake their professional job and training, and it has echoed throughout all levels of teacher preparation programmes and schools of education in South Africa and globally. ICTs have ushered in a significant shift in how we deliver, develop and enable teaching and learning in preservice teacher education programmes, which has now been immensely enhanced by the impact of COVID-19 in schools and universities around the world (Burrows, et al., 2021; Olawale & Mutongoza, 2021). These tensions between teachers, teacher educators, and pre-service teachers have resulted in uneven adoption and comprehension of ICTs and how they might be applied to different curriculum areas (Kozma, 2003; Burrows, et al., 2021).

Thus, while different attitudes/beliefs of teacher educators, programme needs, and institutional structures have influenced teacher education programmes and the use of ICTs, thus creating tension within the programme, Burrows et al. (2021) argued that this tension can result in pre-service teachers having divergent perspectives on technology use in the classroom, and these perspectives can be facilitated or blocked by their interactions with mentor teachers and teacher educators. In terms of teacher educators' views and attitudes, some regard 21st-century students as "digital natives," incorrectly expecting that pre-service teachers will use teaching technologies efficiently in the classroom because of their experiences with ICTs. However, studies reveal that the "natives" can largely use well-known, "light" technologies, such as social media applications, but have not yet mastered the usage of sophisticated technologies or applications (Lei, 2009; Burrows et al., 2021; Mncube, Olawale, & Bitso, 2021).

In teacher education programmes, there are numerous possibilities for discipline-specific technologies that mathematics educators can use to promote best practices. These include geometrical microworlds such as Geometer's Sketchpad, LOGO (a programming language and/or a positional geometry), which help think about conceptual issues (McGehee, 1998; Burrows, et al., 2021), and Geogebra (freeware available on the internet that can be used to investigate these same topics as well as other ideas from algebra and other secondary mathematics subjects) (Burrows, et al., 2021). Given the complexity of some digital tools, it is advised that pre-service teachers become familiar with a range of these tools. This is because schools and other institutions of learning have access to a variety of technologies, including hand-held graphing calculators and an internet-based freeware tool for graphing calculations, which are common tools that the majority of pre-service teachers may or may not have used during their teacher training programme. While these tools go beyond merely demonstrating which button to press to obtain an "answer," they also explore the best questions to ask students to get them to think about mathematical concepts (Adamy & Boulmetis, 2006). Similarly, mathematics teacher educators also make use of these tools to help students develop their conceptual understanding of mathematics and how to teach it. These meaningful representations of complicated topics in mathematics and STEM domains give teacher educators access to strong pre-service teacher support (Monk, 2003; Burrows, et al., 2021). Thus, to support teachers in implementing best practices in instruction and the training of pre-service mathematics teachers, mathematics educators must keep up with technological advancements. However, many of the challenges faced by teacher educators in using technology are the access and affordability of these technologies (Burrows, et al., 2021). Similarly, Johnson, Jacovina, Russell, and Soto (2016) added that teacher attitudes and beliefs, confidence in skills and knowledge, teachers' resistance to technology in the classroom, a lack of access, and insufficient to little or no training are some of the challenges faced by teacher educators in using technology. Thus, while most teacher educators value the use of technology in teacher education, how these ideals are seen in practice varies in subtle and significant ways (Kopcha, Rieber, & Walker, 2016; Burrows, et al., 2021). Hence, the need for the present study.

Collaborative Virtual Environments

A critical component of human development is the capacity for communication and cooperation in the exchange of knowledge. Even in the world's poorest nations, digital inclusion is now a reality due to the popularity of computers and the expansion of the internet. The Collaborative Virtual Environment (CVE), which has been accelerated by the rapid development of Virtual Reality (VR), is an advancement of traditional virtual environments designed to support numerous users taking part in a single interaction

(Passos, Nazir, Mol, & Carvalho, 2016). A CVE is described by Santos et al. (2002) as the intersection of collaborative systems research and virtual reality research. As seen in several fields, such as medicine (Riva, 2003), education (Di Blas & Poggi, 2007), and entertainment (Linden Lab, 2009), CVEs are emerging as an alluring way to enhance computer-assisted activities in the most diverse sectors. As such, CVEs offer users interactions through simulations of the actual world and the manipulation of virtual items as it is in the real world, bringing a fresh viewpoint to collaborative group work learning (Passos, Nazir, Mol, & Carvalho, 2016). According to Redfern and Galway (2002), when difficult subjects are being discussed, CVEs can assist in meeting some of the communication needs that have long been acknowledged as essential to interactive discussion. In education, the usage of CVEs encourages engagement of the individuals by dynamically delivering learning activities, training, enjoyment, and many more (Redfern & Galway, 2002). CVEs also can support cutting-edge and successful distance learning strategies, such as debate, simulation, role playing, discussion groups, brainstorming and project-based group work. As shared understandings are negotiated and formed across gaps in knowledge, skills, and attitudes, human-to-human interactions can be emphasised (Redfern & Galway, 2002; Passos, Nazir, Mol, & Carvalho, 2016). As a result, Passos, Nazir, Mol, and Carvalho (2016), posit that when using CVEs, users must freely move around the virtual environment (spatial sharing), and they can communicate with other users (presence sharing). A user must also be able to see the actions of other users in real-time (time sharing), which improves situation awareness between users (Passos, Nazir, Mol, & Carvalho, 2016).

Virtual Reality (VR) application in teacher training programmes

Virtual worlds are always three-dimensional. They can offer an interactive environment with a level of interactivity that is much higher than what is physically practical. Thus, when used as a tool for mathematics education, virtual reality should ideally enhance learning across a variety of mathematical fields. There are several areas of higher mathematics where VR can be used, including analysis (such as complex functions), linear algebra, differential calculus and geometry, projective geometry, and higher dimensional geometry, to mention a few (Kaufmann, 2011). Hence, the use of VR becomes vital in teacher training programmes because it can fill the gap between the real-world context that nature provides and the theoretical realm of notions and ideas. According to Azuma (1997), a subset of virtual reality is augmented reality. Through the use of virtual reality technology, users are entirely immersed in a constructed environment. The user is unable to view the real world outside while immersed. In contrast, the user can view the real world with virtual things superimposed or blended in with it using augmented reality (Kaufmann, 2011). Therefore, to complement reality rather than fully replace it, augmented reality is used. In an ideal world, the user would think that actual and virtual items were present in the same area. Kaufmann (2011) posits that the following three qualities are necessary for an AR-3D Geometry system in terms of the technology being used: actual-time interaction, combining actual and virtual elements, including registration of users and objects in three dimensions.

According to Trien Do and Lee (2007), the practical problems that students encounter when learning descriptive geometry and deciphering technical drawings serve as the impetus for the creation of the ARToolkit 3D geometry system. Thus, Billinghurst, Kato, and Poupyrev (2001) highlight that for user interaction and tracking, the system makes use of ARToolkit. This toolkit is "an open source software that uses a single ordinary web camera to track planar, quadratic markers usually produced on an ordinary office laser printer. It is an extremely cost-effective tracking solution" (Kaufmann, 2011: p.135). This allows users to create challenging applications with numerous tracked interaction devices and artefacts by using a user-definable pattern inside the marker to distinguish between various targets (Billinghurst, Kato, & Poupyrev, 2001; Kaufmann, 2011). Similarly, the system allows users to design standard 3D objects, alter properties, simulate object intersections using two markers, and export results to Virtual Reality Modelling Language (VRML) files using the system's basic functionality. The VRML file is a common file format for displaying interactive 3-dimensional (3D) vector graphics that was created specifically with the World Wide Web in mind. Thus, the AR-3D Geometry system can assist pre-service mathematics teachers in increasing their study performance, and it is a pedagogical tool for their educators to create more captivating and understandable lectures. Furthermore, the use of the AR 3D Geometry system in the preparation of pre-service mathematics can enhance practical learning, higher students' engagement and interests, improve collaboration capabilities and make learning materials accessible anytime-anywhere.

THEORETICAL FRAMEWORK

According to Tondeur, et al. (2017), the incorporation of instructional technology should be studied as a complex and interrelated factorial system. Hence, this study employed Dogan, Dogan and Celik's (2021) model of technology use as shown in Figure 1 below. This model investigated how educators felt about integrating instructional technology in various settings (school versus home) and circumstances (contact versus remote teaching). The three components of the framework include technology use, the factors that have been demonstrated to have an impact on it and the relationships between each of these elements and technology use. As such, the framework argues that teachers' perceived proficiency in a specific technology is associated with their perceived value (i.e., belief) in that technology. As educators acquire proficiency in utilizing technology inside the classroom, their favorable attitudes towards the efficacy of technology are enhanced. Likewise, the provision of technological support impacts teachers' opinion of their abilities and their confidence in utilizing technology (Dogan, Dogan, & Celik, 2021).

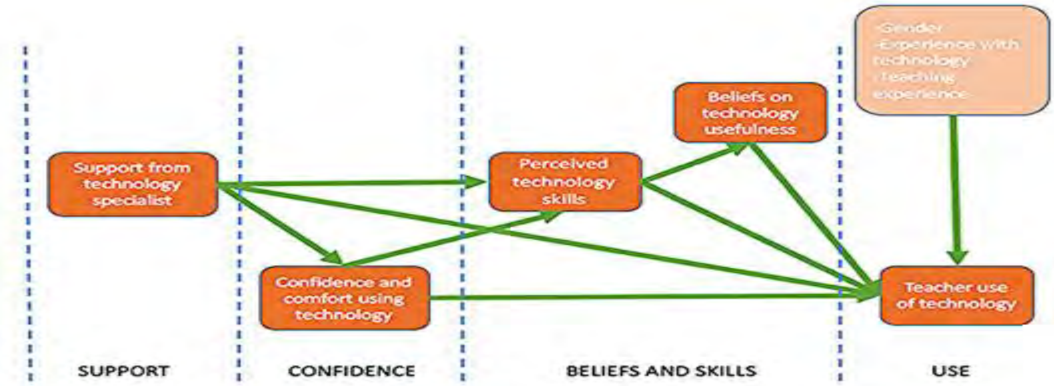

Figure 1. Dogan, Dogan and Celik (2021): interrelationships between the factors and use of technology

The above framework becomes relevant to this study because it highlights that the implementation of educational reform is mediated by educators. Educators opinions about technology or software can encourage or hinder the use of technological resources both within and outside of the classroom. Researchers have thus investigated educators' self-efficacy—or, more specifically, their self-rated capacity—to integrate technology into instruction (Andreassen & Bråten, 2013; Banas & York, 2014; Gomez, Trespalacios, Hsu, & Yang, 2022). The findings revealed a generally favourable, though not necessarily direct, correlation between educators' views towards and confidence in using technology, as well as its successful integration. Similarly, studies examining how expert support affects technology integration have shown conflicting findings. For instance, Ritzhaupt et al. (2012) discovered that the technical staff's overall support of instructors and technical coordination had a direct (beneficial) impact on the integration of technology. In this area, Razak et al. (2018) found no appreciable differences. Inan and Lowther (2010) found a direct but positive association between instructors' perceptions of the value of the technical and pedagogical help they received during their pilot research. These disagreements show how important it is to plan for the supply of the specific support that instructors need.

Statement problem

The impact of technology-enhanced learning treatments has been found by several authors (Habibi, et al., 2021; Olawale & Mutongoza, 2021; Wong & Wong, 2021) to be significantly correlated with students' performance. However, its use in the teaching and learning of mathematics has been found challenging (Drijvers, 2013; Francom, 2020), especially in the preparation of pre-service mathematics teachers. These challenges are attributed to the pedagogical design of the tools, the role of the educators and the educational context (Drijvers, 2013). In the face of these challenges, the COVID-19 pandemic also presented new obstacles, which include domestic and communal barriers (such as obstacles at the educational institution, in the curriculum, in technology, in finances, in people's personal and home lives, and communities) (Christopoulos & Sprangers, 2021). All of these issues highlight the demand for structured, evidence-based solutions that can speed up the adoption of contemporary educational technologies in a variety of learning environments (such as online, face-to-face, and blended learning) and assist educators and students in achieving their academic and personal objectives. Hence, this necessitated the need to examine the factors that impede the use of Collaborative Virtual Environments (CVEs) in the preparation of pre-service mathematics teachers and how CVEs can be effectively integrated in mathematics teacher education programme.

Research Questions

- i. What factors impede the integration of Collaborative Virtual Environments (CVEs) in the preparation of pre-service mathematics teachers?
- ii. How can Collaborative Virtual Environments (CVEs) be effectively integrated in the preparation of pre-service mathematics teachers?

METHOD

Underpinned by a constructivist paradigm, the study employed a qualitative research approach defined by Ormston et al. (2014) as naturalistic and interpretative which is concerned with investigating phenomena from an inner perspective, working from the viewpoints and accounts of the research participants. The qualitative approach was employed to gain a clearer perspective of the factors that impedes the use of CVEs in the preparation of pre-service mathematics teachers and how Collaborative Virtual Environments (CVEs) can be effectively integrated in the mathematics teacher education programme. A case study research design was also employed. As Yin (2014) affirms, a case study is the most appropriate strategy when contextual conditions are relevant to the phenomenon under study. Single cases are the most appropriate to confirm or challenge a theory or to represent a unique or extreme case. A single case study allows the researchers to observe and get in-depth information directly from the case, analyse it and relate it to the theoretical part (Yin, 2014).

Thus, the population of the study consisted of pre-service mathematics teachers, their educators and the Head of Department in the Faculty of Education of an institution in the Eastern Cape province, South Africa. From the population, a purposive sampling technique was used to identify twenty-five pre-service mathematics teachers, two teacher educators and one Head of Department with the expectation that they would report unique and interesting data regarding the phenomenon under investigation. As such, data was gathered through semi-structured interviews with the participants, with each interview having a duration of approximately fifteen (15) minutes. Leavy (2017) argues that interviews are highly valuable as they allow researchers to delve deeper and gain a comprehensive understanding of the problem by exploring the perspectives of the participants. In order to guarantee the reliability of the data, the researchers employed triangulation, which involved analyzing many sources of information (Leavy, 2017). Once the data was collected, the study employed a thematic data-analysis procedure proposed by Braun and Clarke (2006), which comprises six steps: gathering data; generating categories, themes, and patterns; coding data; testing emergent understanding; searching for alternative explanations; and report writing. For data presentation, the twenty-five pre-service mathematics teachers were differentiated through fictitious names such as PSMT 1, 2, and 3, to mention a few, ME 1 and ME 2 were used to represent the two educators and HOD for the Head of Department. The participants' confidentiality, anonymity, and privacy were observed for ethical purposes.

RESULTS AND DISCUSSION

The present study examined the factors that impede the use of Collaborative Virtual Environments (CVEs) in preparing pre-service mathematics teachers and how Collaborative Virtual Environments (CVEs) can be effectively integrated into the mathematics teacher education programme. Hence, the results and discussions were presented under the following sub-headings:

i. Factors that hinder the integration of Collaborative Virtual Environments (CVEs) into the preparation of pre-service mathematics teachers; and,
ii. Integration of Collaborative Virtual Environments (CVEs) in the preparation of pre-service mathematics teachers.

Factors that impede the integration of CVEs in mathematics teacher's education programmes

To fully comprehend the necessity of Collaborative Virtual Environments (CVEs) in mathematics teacher education programme, it becomes paramount to understand the factors that impede its use. As such, participants were asked: "What factors hinder the use of collaborative Virtual Environment in your teacher education programme?" Research findings revealed that negative attitudes towards change, technical limitations, costs and time constraints, assessment challenges, equity and access issues and lack of training and support are some of the factors that hinder the integration of CVEs. For instance, a participant stated:

> *…. during the course of our programme, we tried to make sure that the transition from face to face learning to collaborative environment was smooth and that both educators and pre-service teachers could make use of any platforms or digital tools available to them for ease of teaching and learning. However, with the implementation of collaborative virtual environment, there were issues such as the lack of training and support for academic staff, as well as students. Also, remember that the use of this software is costly and requires a certain resource base and not all the students' phones are capable of supporting AR applications. …as a result, we were all overwhelmed by the demands of learning using new software and technologies, especially without adequate training and/or ongoing support for the departmental staff members and the university at large* (H-0-D).

Similarly, a participant iterated:

> *The major reasons why I was unable to make use of this software or promote a collaborative virtual environment in the training of pre-service students is not only because of the lack of support but because of factors such as technical issues and time constraints. For instance, the implementation of collaborative environment requires a stable internet connection and proficient hardware, and these students do not have access to both reliable internet, as well as appropriate devices which make its use very challenging. In addition, CVEs takes a lot of time because they require sufficient time for planning and preparation, and the time to create and manage this environment is also challenging given that you still have more modules to teach* (ME-2).

While participants highlighted issues such as a lack of training and support, time constraints and technical limitations, others believed that factors such as assessment challenges and negative attitudes hinder CVEs integration. For instance, a participant argued:

> *… I believe most of our lecturers couldn't make use of sophisticated software for teaching because of the sudden transition that occurred during the pandemic which caught them unaware, and this makes the use of this software/platform very difficult to be implemented.. This is because, when we moved learning online, everyone wanted assignment as form of assessment because it allows us more time to consult website and other sources for answers – and our lecturers were cool with that. This however shows that they [lecturers] were not sufficienty prepared because we all know that traditional assessment methods won't work in a collaborative virtual environment. Thus, finding an appropriate way to access hundreds of students learning and progress in this environment will be challenging* (PSMT-14)

Similarly, a participant added:

I believe that one of the major problems that hinders our teacher education programme from using this type of virtual environment is how to assess students while using these types of teaching and learning environments because a lot of us are from rural areas, and we do not have equal access to technology and reliable internet connections, as others who are from the cities. So, setting up a standard assessment format that suits this particular form of teaching can lead to mass failure amongst students and create inequalities (PSMT 3).

Furthermore, an educator posited:

… I strongly believe that a negative attitude towards change on the part of both academics and students is one of the major stumbling blocks to the integration of Collaborative Virtual Environement in teacher education programes.. Some of us [mathematics educators] have a negative attitude towards the use of technology or new software in our teaching and learning activities because of several beliefs. For example, there are challenges of not knowing how to upload materials, and assess the students after teaching, etc, because we are not techno savvy…. These challenges affect our [mathematics educators] attitudes and undermine the successful implementation of technology in the preparation of sound and competent pre-service mathematics teachers needed in the fourth industrial revolution era (ME-1)

Research findings revealed that the integration of Collaborative Virtual Environment was hampered by several factors which include resistance to change, technological limits, costs and time constraints, assessment difficulties, equality and access issues and a lack of training and support. This finding corroborates those of Kaufmann (2011) who argued that due to the lack of a large market for both virtual or augmented reality products, the hardware is pricey. Furthermore, Kaufmann (2011) adds that technical complexities and the support for only a few students are the challenges of using CVEs - as opposed to the large crowd of students we now have in some of our teacher education programme classrooms. Similarly, other studies (Gillies & Boyle, 2010; Geszten, et al., 2018) aver that educators' perceptions of their ability, a lack of sufficient understanding of how to effectively implement collaborative virtual environments, not being aware of what the environment entails or its potential educational values, its navigation and manipulation, visual awareness and visibility problems are some of the factors that impede its integration. The findings also resonated with the framework proposed by Dogan, Dogan, and Celik (2021) who contend that the educators' perceptions of their ability to use a particular technology or software are correlated with their beliefs about the technology's perceived utility. This is because the educators' positive attitudes regarding the value of technology grow as they develop their ability to use it. The view of educators' digital competence and confidence is also impacted by technology support. According to Dogan, Dogan, and Celik (2021), the educators' willingness to implement technology can be enhanced through technical and general support.

Integration of CVE in the Preparation of Pre-Service Mathematics Teachers

After ascertaining the factors that impede the use of CVEs, it becomes vital to examine how CVEs can be effectively integrated into mathematics teacher education programmes. As such, the research participants were asked: "How can CVE be integrated into the preparation of pre-service mathematics teachers?'' Research findings revealed that for CVEs to be effective in teacher preparation programmes, mathematics educators should encourage the simulation of classroom scenarios, facilitate group discussions and cooperative learning and participat in virtual professional development opportunities. For instance, a participant stated:

For CVE to be effectively integrated into teacher education programmes, the first thing that we [mathematics educators] need is a professional development programme that focuses on the creation and relevance of these virtual environments. These opportunities which may be presented in the form of online workshops and webinars, etc, are capable of providing an in-depth knowledge on these virtual environments and how to create, use and assess students (ME-1).

In addition, another participant concurred and averred that:

…So, to promote the use of CVE in the training of mathematics teachers, our educators must be able and willing to create virtual classrooms that allow pre-service teachers to engage in lesson planning, teaching practices and student interaction. Educators must encourage online forums where students can engage in group discussions, share resources and collaborate on several mathematics-related projects. This will acquaint them [pre-service mathematics students] with the type of environment that they [mathematics educators] want to promote and develop in them [pre-service mathematics students] and the communication and teamwork skills needed in the world of work (H-0-D)

Similarly, research findings also revealed that mentoring programmes, peer collaboration and feedback are how CVEs can be effectively integrated into the preparation of pre-service mathematics teachers. For instance, a participant stated:

... now that we are working in the new normal after the pandemic outbreak, I feel it is best to embrace a new way of teaching and learning. Therefore, using CVE in the preparation of pre-service teachers should be embraced by all educators, and for us to effectively use this type of software or environment, the management must provide us with different mentoring programs which pair novice mathematics educators with experienced mentors. This type of program can be facilitated online, within our university, or with other university staff members. This allows us to get proper guidance,

> *support and feedback in different areas, such as classroom management, lesson planning and conducting assessments* (ME-2)

Similarly, another participant addes:

> *Our educators have told us that we must be flexible and creative given that we are teachers of the 21st century and for us to be able to shift from the traditional way of teaching, we need to be exposed to different teaching methods such as this software. As a result, this teaching and learning environment can only be effective if we are provided with adequate mentoring and supervision in which mentors can observe and provide guidance* (PSMT-11)

Another pre-service teacher posited:

> *I believe this type of virtual environment can be implemented successfully if teacher educators can facilitate collaborative spaces where we [pre-service teachers] can work together on lesson planning, curriculum planning and problem solving. This kind of space allows us [pre-service teachers] to learn from one another, exchange ideas on this learning platform and provide feedback on our learning, as well as teaching strategies* (PSMT 8)

For a Collaborative Virtual Environment to be successfully implemented in teacher education programmes, both educators and pre-service mathematics teachers require proper guidance and support. Research findings further revealed that for CVEs to be effective in teacher preparation programmes, mathematics educators should encourage the simulation of classroom scenarios, facilitate group discussions and cooperative learning and participate in virtual professional development opportunities. Similarly, the findings revealed that the implementation of CVE will be effectively integrated if educators and pre-service mathematics teachers are provided with mentoring programmes, peer collaboration and feedback. As a result, clear expectations, regular feedback and opportunities for reflection should be prioritised when considering the integration of CVEs into the pre-service teacher training programme to maximise the learning outcomes. This finding corroborates that of Perifanou, Economides, and Nikou (2022) who argued that to integrate augmented reality into education successfully, educators must be self-aware, reflect on their AR knowledge and skills, get training, experiment with AR and work with other educators. In addition to this, administrators of educational institutions should get familiar with AR, spread the word about it and educate students and teachers about its benefits (Perifanou, Economides, & Nikou, 2022). Similarly, Alalwan, et al. (2020) add that facilitating collaborations between teachers, trainers, educational content creators, curriculum designers, learners, alumni, employers, experts and other schools are also some of the ways to effectively integrate augmented reality in educational institutions. Therefore, while the effective integration of CVEs in the preparation may be challenging, it is impossible to prevent the use of technology in education given that it now affects how we learn and live. As such, all stakeholders must be encouraged to embrace the new normal.

CONCLUSION

It is widely accepted that collaborative virtual environments can aid in teaching and learning. Therefore, it is important to consider both the educators' and pre-service mathematics teachers' opinions in order to successfully implement CVEs in teacher education programmes given that teachers are typically the key advocates for any technological integration in instructional practice. Thus, while the secret to achieving a better learning experience in teacher education programme is to figure out how to make use of the advantages of the available new technologies, the difficulty is increasingly evolving into a didactic and pedagogical one. Thus, this study concludes that although factors such as resistance to change, technological limits, costs and time constraints, assessment difficulties, equality and access issues and a lack of training and support may hinder the use of CVEs, the integration of CVEs could still be successful. This would be achievable in teacher education programmes if mathematics educators could encourage the simulation of classroom scenarios, facilitate group discussions and cooperative learning and participate in virtual professional development opportunities.

Ethics and Consent: Ethics committee approval for this study was received from the Ethics Committee of University of Fort Hare (Date: 13 November 2019; Approval Number: REC-270710-028-RA Level 01).

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