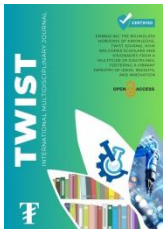
DOI 10.5281/twist.10049652#468

TWIST, 2025, Vol. 20, Issue 3, pp. 142-156

TWIST

Journal homepage: www.twistjournal.net



Transforming and Sustaining Digital Mathematics Teaching and Learning in Higher Education Institutions in South Africa:

A Literature Review

Thabisa Maqoqa
Faculty of Education, Department of Adult and Education Foundations,
Walter Sisulu University, South Africa
ORCID: https://orcid.org/0000-0002-9191-3299

Abstract
The digital transformation in the global higher education sector determines the future course of a sustainable education management strategy. In this era of the Fourth Industrial Revolution (4IR), utilising technology-driven teaching methods to enhance learning, assessment, and teaching is essential. This paper examines how digitising education improves the quality of teaching at higher education institutions in rural regions. This research used secondary data from various authors to support its qualitative research approach. This information was utilised to gather public and peer-reviewed journals, online materials, and pertinent textbooks. Many authors claim that students acquire the mindset and abilities to tackle complex problems through digital transformation in mathematics education. This paper will focus on the teaching and learning of Mathematics through digitisation and explore how this transformative initiative can be maintained in rural higher education institutions, using a specific university as a case study. In this context, difficulties faced by students and teachers were revealed through primary sources, including policies and verbal informants. This paper is grounded in Wenger's (1998) theory of the virtual community of practice. According to the study results, teachers and students concur that insufficient infrastructure, poor internet connectivity, and power outages hinder technology integration in the classroom. It was demonstrated that the ability of participants to participate in online teaching and learning equally was influenced by their challenges in accessing data and using devices. As per the recommendations, management ought to arrange training workshops and online resources to equip teachers and students for digital environments. To tackle the issues emphasised in this paper, teachers should evaluate online resources to determine if they are easily accessible, affordable, and user-friendly. Nonetheless, these issues must be addressed to promote the adoption of technology.

Keywords
Digital Transformation, Sustainability, Technology-based, Pedagogy, Teaching

INTRODUCTION

South African universities have incorporated digital technology into mathematics training, changing it dramatically. The COVID-19 pandemic accelerated the digital transformation in mathematics education by forcing a speedy switch to online and distance learning. Chirinda, Ndlovu, Spangenberg (2021) and Naidoo (2020) have examined the pros and cons of utilising digital platforms to teach maths in emergencies. Lavidas and Delima (2022) examined how digital teaching tools and full instruction models might enhance interactive mathematics learning. The COVID-19 epidemic boosted online and e-learning usage. Mulenga and Prieto (2020) and Mpungose (2020) explored digital platforms in mathematics education during the pandemic and online learning. Modern teaching is progressive, and technology is increasingly integrated into society and individuals (Mhlanga & Ndhlovu, 2023). Recent developments have raised questions about the feasibility and usefulness of digital mathematics instruction at South African institutions. The rapid transition to online learning has opened creative and flexible opportunities, but it has also shown gaps in access, methodology, and student participation.

Cranfield et al. (2021) and Chirinda et al. (2021) examined how students felt about emergency e-learning and how disadvantaged instructors taught mathematics during the lockdown. This research emphasises the necessity for long-term planning to satisfy South African students' diverse needs and the difficulties of the digital mathematical revolution. Even while digital mathematics teaching methods at South African institutions have improved, their sustainability is unknown. Researchers have neglected higher education's transition and sustainable growth, which warrants more investigation (Filho et al., 2018). According to research on student performance, online maths education needs inclusive practices and pedagogical solutions (Kizito, Munyakazi & Basuayi, 2015) and decolonising technical and pedagogical content knowledge (Khoza & Biyela, 2019). To bridge this knowledge gap and give equitable access to high-quality education, we must examine how digital technologies may be effectively integrated into mathematics instruction. This literature review examines how digital mathematics education has changed and will change in South African institutions.

The long-term viability of mathematics education depends on using practical pedagogical approaches and digital technologies to raise student achievement. The significance of using ICT in higher education to advance sustainability and conform to the SDGs is highlighted in the research conducted by Alonso-García, Aznar-Diaz, and Caceres-Reche (2019). According to Balogun, Marks, Sharma, Shekhar, Balmes, Maheng, Arshad, and Salehi (2020), in this digital era, sustainability teaching tools are essential for cultivating abilities that permit sustainable mathematics instruction. With the increasing use of digital resources, South African institutions' mathematics education is evolving fast.

Also, researchers Dewa and Ndlovu (2022) discovered that mathematics education instructors may benefit from using ICTs by including digital tools in their lessons. For digital mathematics courses in South Africa to be sustainable, we need technology that can endure and fulfil societal and educational demands. Technology access varies among South African pupils based on socioeconomic status (Ng'ambi, 2018). South African HEIs highly value incorporating technology and digital learning. By lowering the barriers to high-quality education for all students, these technologies support Sustainable Development Goal 4 and encourage lifelong learning. With consequences for online learning, Semenya's (2020) research highlights the critical roles that institutions in South Africa must play in maintaining technology transfer offices. The potential of digital technology to support mathematics education in the face of disasters like the COVID-19 pandemic is further explored by Mafenya (2022).

According to Estermann, Pruvot, Kupriyanova, and Stoyanova (2020), automation "can lead to efficiency surplus; however, this is often accompanied by increased demand and thus increased consumption of raw materials." To be effective and long-lasting, online education in higher education needs careful planning and consideration of all relevant factors. According to Bakry, Dabab, and Khalifa (2019), even though teaching and learning are the foundation of education, academics are concentrating on reforming higher education, particularly sustainability learning. Nevertheless, there is a dearth of literature on integrating transformational learning and sustainable development into college courses. The goal of South African higher education institutions is to provide accessible, high-quality education to all students, and digital learning and technology integration are growing in importance to achieve this goal.

Digitisation has benefits and drawbacks, but it also has the potential to generate positive feedback loops. Though digitalisation "can lead to efficiency surplus," Estermann et al. (2020) point out that raw material consumption usually rises with demand. Teaching and studying are fundamental to education, according to Bakry, Dabab, and Khalifa (2019). Effective, sustainable, and scalable digital pedagogy in higher education requires meticulous planning and implementation. Both sustainable education and the function of universities as places for change are receiving more and more focus. In 2018, Filho et al. made a discover.

Background

Amidst the COVID-19 epidemic and other recent events, mathematics education in South African institutions has seen profound shifts. The trend towards digital mathematics education has prompted concerns over digital technologies' long-term viability, fairness, and efficacy in improving mathematical education. South African institutions' difficulties in shifting from conventional in-person instruction to online learning modes during the epidemic have been highlighted in studies like Angu's (2022) and Mpungose's (2020). Factors like racial inequality, socioeconomic differences, and different educational backgrounds amplify these issues and further widen the digital gap in university settings. Accessibility and inclusion have also been highlighted by the digital revolution of mathematics instruction at South African institutions. To guarantee that all children, especially those from low-income families, have equal access to high-quality education, Woldegiorgis (2022) stresses the need to close the digital achievement gap. Considering the uncertainties caused by the pandemic, student support services in higher education must undergo continual adaptation and evolution, as shown by Naidoo's (2022) study. This will ensure that all students have equitable access and success. Research on faculty and student preparedness to use digital platforms is becoming more important as maths teaching in South African universities undergoes a complicated digital change. Research by authors like Tatira and Kariyana (2022) and Villarreal, Villa-Ochoa, and Galleguillos (2022) shows that maths education must be ready to incorporate technology, calling for new methods of instruction and professional development for educators to backup successful online lessons. South African institutions may create sustainable and prosperous digital learning environments that respond to the different requirements of students and educators by addressing concerns of access, inclusion, preparedness, and pedagogical innovation.

Considering the current COVID-19 epidemic, Mohalik and Sahoo (2020) said that instructors have wholeheartedly embraced teaching and learning in an online format. Many educators find themselves emotionally, socially, financially, and technologically unprepared due to the hasty transition to online learning. As a result of their lack

of familiarity, instructors also encounter challenges when dealing with technology pedagogical techniques (Mohalik & Sahoo, 2020; Kulikowski, Przytula & Silkowsi, 2021; Taner, Akyıldız, Gülay, & Özdemir, 2021). Higher education institutions (HEIs) in South Africa have responded to these difficulties by launching programmes to revamp and maintain online education. These endeavours include online course and programme development, digital pedagogy and instructional technology adoption, and digital infrastructure and support service enhancement. There is a growing need for more trustworthy data to support the transformation and sustainability of online education in South African universities. However, the significance of efficiently using this data to execute digital learning techniques must be acknowledged. The sources state several problems with digital learning and instruction in South Africa's educational system. These difficulties include adaptability, equality, efficiency, quality, sustainability, scalability, and localisation/customisation. The government of South Africa has a chance to fix the problems of inequality and inconsistencies in the country's higher education system because of the COVID-19 epidemic (Armoed, 2021). More teacher training in digital technology is necessary, as the epidemic has shown since the present inadequate higher education system. Therefore, South African universities and colleges must prepare for the post-pandemic era by developing ways of teaching and research that will guarantee students' success in the classroom and keep them from falling short of expectations. The chapter ends by stating that to accomplish Sustainable Development Goal 4, which is to ensure that all people have access to high-quality education and opportunities to continue learning throughout their lives, it is crucial to emphasise factors related to efficiency, longevity, and scalability in digital learning (Rashid & Yadav, 2020). These elements will aid the adoption and maintenance of online pedagogy at South African universities (Armoed, 2021). Higher education institutions in South Africa may tackle massification, demography, and the need to compete in the 21st century by using technology and trustworthy data. Sustainable development must be part of university curricula for the kind of change and education that the world needs now (Filho et al., 2018). The involvement of students and the dedication of teachers are essential for this integration to succeed.

There is a rising awareness among South African higher education institutions of the necessity to revamp and maintain digital teaching and learning in light of the COVID-19 pandemic's effects on these systems. Some examples of this approach include creating hybrid campuses that cater to the needs of both students and teachers and making use of online learning and virtual classrooms.

As a result, we may learn from the pandemic's achievements and failures, calculate the costs, and perhaps scale up these technologies to increase access (Mhlanga & Studies carried out by Moloi in the year 2020. Some worry that low-income kids will worsen due to the pandemic's shift to online education (Damani, Daltry, Jordan, Hills, & Evans, 2022). Although several large nations, such as Rwanda and the Democratic Republic of the Congo, have not yet issued clear instructions, the epidemic is expected to increase the use of computers in classrooms worldwide. It is only via this change that issues like inequality, inadequate educational opportunities, and the need for better RLSs can be effectively addressed. According to Luong and Arnold (2020), four factors must be considered to launch an online learning community successfully. Here are some things to think about: making sure that all kids can use the internet and digital tools the same; making sure that teachers have enough support and training to use digital tools and platforms effectively; addressing cyber-risks and making sure that students are safe when using digital tools; and lastly, thinking about the bigger picture of systemic effects and obstacles that could make RLSs useless. Following the COVID-19 outbreak, concerns about ensuring all students have fair access to high-quality digital technology have come to light. Digital technologies have become more prevalent in the classroom after the COVID-19 epidemic, particularly in South African institutions (Damani et al., 2022). In order to guarantee that all students may continue to get an education, these institutions must now maintain and improve digital mathematics teaching and learning. The following parts of the inquiry's findings are presented based on a literature review.

Research Question

The following research question guided the study:

What are the key factors influencing the successful transformation and sustainability of digital mathematics teaching and learning within HEIs in South Africa?

EMPIRICAL LITERATURE REVIEW

The key factors influencing the successful transformation and sustainability of digital mathematics teaching and learning within HEIs in South Africa

Rassool and Dissanayake's (2019) literature review highlighted the lack of research on digital transformation (DT) strategies and their implementation across industries. It is crucial to approach digital transformation strategically and prioritise which issues must be addressed. To assist managers in creating and implementing a digital transformation plan, more research is required to understand how businesses handle the newest digital transformation possibilities and difficulties (Wiesböck & Hess, 2016).

By bringing together the views of politicians, academics, and the business sector, the utilisation of ICTs may hasten the attainment of Education 2030 Agenda goals, according to a 2018 UNESCO study (Elfert, 2019). Since they promote student-centred learning and accelerate educational change, ICTs may benefit all educational institutions. Constant exposure to ICTs alters pupils' perceptions. Students with a good attitude towards technology in the classroom are likelier to master it and learn more deeply (Barakabitze, 2014).

One of the most significant changes in South African higher education is the rise of digital classroom tools. The COVID-19 pandemic has accelerated online and remote learning use at SAUs, notably in mathematics. Watermeyer, Crick, Knight, and Goodall (2020) and Timmis and Muhuro (2019) recommend decolonising and restructuring university institutions to ensure digital education inclusiveness and accessibility. The internationalisation of higher education highlights the need for global perspectives and collaborations in designing digital education initiatives at SAUs, according to Rensburg et al. (2015). Villarreal et al. (2022) found that prospective mathematics teachers' pandemic experiences highlight the need to rethink maths teacher training curricula to better incorporate digital resources into teaching. Studying how SAUs use digital education, particularly mathematics, is crucial.

Digital technology has expanded and deepened education. Numerous disruptive technologies, such as smart devices, IoT, AI, AR, VR, blockchain, and software, provide prospects for T&L progress (Gaol & Prasolova-Førland, 2021; OECD, 2023). In response, educational systems worldwide have emphasised the adoption of ICT integration plans or policies and increased their spending in this area (Banerjee, 2021). (2019 Slander). Using ICTs in education led to issues with understanding, adapting, and designing educational systems in line with current technology (Balyer & Öz, 2018). Studies suggest that school technology integration investments have failed (Timotheou, Miliou, Dimitriadis, Sobrino, Giannoutsou, Cachia, Mones, & Ioannou, 2023). These issues worsened when the COVID-19 pandemic forced all schools to convert to online learning (Daniel, 2020). Due to the usage of digital technology in online education, Chachia, Chaudron, Di Gioia, Velicu, and Vuorikari (2021) say questions have developed over the method, nature, scope, and effectiveness of digitalisation in schools. Rosak-Szyrocka et al. (2022) and Di Pietro et al. (2020) found that schools lacking digital competency and knowledge had increased inequalities, inequities, and learning losses. These results put schools under pressure to increase their digital capabilities and digitalisation (European Commission, 2020; Costa, Castano-Munoz, Kampylis, 2021). Digitalisation affects many aspects of a school's growth, offering the potential for fundamental improvement (OECD, 2021; Rott & Marouane, 2018; Delcker & Ifenthaler, 2021). Technology and infrastructure are vital, but the process is complex and requires revolutionary changes (Pettersson, 2021). Govender and Mpungose (2022) found that online education in South Africa exacerbates inequality and requires considerable assistance for disadvantaged students.

An extensive literature analysis by Aboytes and Barth (2020) examined the conception and implementation of sustainable education and transformational learning. According to the research, transformative learning theory may help build long-term educational interventions and evaluate student progress towards these objectives. Technology is being employed in South African education to counteract massification. However, we must reorganise our educational system to meet the requirements of a modern, competitive society while ensuring that educational technology improvements consider the country's demographics and history (Hlatshwayo, 2019).

Several recent studies have shown opportunities and challenges for teaching and learning at South African HEIs. There are several obstacles to overcome in online education, including teachers' resistance to change, insufficient support from institutions, an absence of an online learning culture, academics' exclusion from online education development programmes, and many more (Cant, 2021). The COVID-19 pandemic has shown that there are still inequalities across different educational institutions. For instance, some schools lack the technology to adequately provide online classes (Ngoatle, Mothiba & Ngoepe, 2022). Reforming educational procedures and curriculum production is necessary to better align knowledge and skills with societal expectations, according to Ramonyai et al. (2022). National awards in South Africa's higher education system reward outstanding instruction and highlight the value of professional development opportunities for faculty (Baleni et al., 2022). Online learning management systems are becoming more popular for universities to assess students and accomplish educational objectives (Mahabeer & Pirtheepal, 2019). The success of these schools' online education programmes hinges on removing the perceived obstacles to using cutting-edge online education strategies (Isabirye & Dlodlo, 2014).

Redressing linguistic and social inequities has led to initiatives to increase the use of African languages in schools, which reflects the broader transformation in South African higher education. This has been prompted by the structural and funding changes historically black universities have experienced since apartheid ("The Challenges of Historically Black Universities in the Post-Apartheid Era: Towards Educational Transformation", 2017). (Hornberger, 2014; Wildsmith, 2012). As a result of the COVID-19 epidemic, several schools have instituted new regulations and procedures, particularly those that prepare students for careers in health care (Asamani, Christmals, Nyoni, Nabyonga-Orem, Nyoni, Okoroafor & Ahmat, 2022). The shift towards online learning and teaching platforms has highlighted access disparities, especially for students from disadvantaged backgrounds (Landa et al., 2021). Students ' social learning indicators increased after learning about sustainable development using participatory techniques (Sousa, 2021).

Lembani et al. (2019) found that online education has worsened the digital divide and other disparities in South Africa, particularly between urban and rural pupils. Equal access to online learning for underprivileged groups remains challenging (Chirinda et al., 2021). Some have sought to improve maths instruction via digital means by collecting data on how pupils have used digital tools throughout the pandemic (Oke & Fernandes, 2020). Mathematical education modules and the efficacy of blended learning approaches have been the subject of research (Mhlanga et al., 2022). Despite the potential for technology to revolutionise education, issues with its incorporation into mathematics classrooms continue (Ngoatle et al., 2022). Mathematics teachers often struggle with basic computer skills, which limits their ability to use digital tools effectively in the classroom (Woldegiorgis, 2022). To thrive in modern online courses, students from low-income schools need to have their digital literacy abilities addressed (Ubah et al., 2020). Furthermore, the Fourth

Industrial Revolution (4IR) presents opportunities and challenges for South African institutions; hence, understanding the motivations for and barriers to digital technology adoption is crucial (Chirinda et al., 2022). We must strive to reduce the digital achievement gap, increase digital literacy, and discover innovative uses of technology in the classroom if we want all students to have equitable access to a high-quality education.

Digital pedagogy can revolutionise South Africa's higher education system. According to Bakry, Dabab, and Khalifa (2019), education's pillars are learning and teaching. A sustainable framework for mathematics education must prioritise research into pedagogy that encourages students to think critically. We are also during the Fourth Industrial Revolution (4IR); thus, it is important to look at how education may include technology to help students make better decisions and solve problems more critically (2023: Singh, Oke, Kineber, Olanrewaju, Omole, Samsurijan & Ramli). In the Fourth Industrial Revolution (4IR) era after COVID-19, higher mathematics education must focus on solving real-world problems using mathematical knowledge and skills.

Although digital learning has the potential to alleviate some of the issues plaguing South African schools, the assessment of relevant literature reveals that it is not without its negative aspects as well. The necessity for reliable infrastructure and internet access in remote areas is one of these challenges, along with the digital divide between different socioeconomic groups. Many things get in the way of digital learning in South Africa, making it less effective and harder for people to access. The digital divide creates obstacles to technology and internet access, especially for those living in rural and poor regions (Woldegiorgis, 2022). Liebenberg, Mentz, and Breed (2012) state that this access gap exacerbates educational inequalities. Inadequate information and communication technology support, an e-learning culture, and a lack of institutional backing are further challenges to successful digital learning implementation at HEIs (Shulga, 2023). Digital resources, including records and academic library items, also have challenges in South Africa regarding maintenance (Matlala, Ncube & Parbanath, 2022; Masenya & Ngulube, 2020). One of the main obstacles to efficient data management is the absence of clear guidelines for digital archiving and preservation (Balogun & Kalusopa, 2021). The long-term viability of digital resources depends on the ability of academic libraries to implement modern digital preservation strategies (Masenya & Ngulube, 2020).

Students who prefer to learn in a classroom setting often struggle with factors such as an unsuitable home environment, an inadequate learning attitude, a lack of suitable learning materials, and a tendency towards classroom-based learning (Brazendale, Beets, Weaver, Pate, Turner-McGrievy, Kaczynski, Chandler, Bohnert, and von Hippel, 2021). The logic of networks and technological resources have caused significant changes to the conventional ways of communication. Using digital processes that improve academic research, teaching and learning, and services supplied, they have also transformed the university system over the past many years (Raffaghelli, 2021). The complex and multi-faceted consequences of online education on classrooms in South Africa need further research.

According to Klement, Dostál, Kubrický, and Bártek (2017), the use of ICT tools in education is crucial because it allows for new forms of communication, which are essential for one-on-one interactions between instructors and students, as well as between students themselves, leading to a more personalised approach. Incorporating and using ICT into the curriculum changes the educational landscape and helps transform teaching and learning towards more sustainable practices (Lavicza, Weinhandl, Prodromou, Andic, Lieban, Hohenwarter, Fenyvesi, Brownell, Diego-Mantecón, and 2022). However, there are many obstacles to achieving this objective, such as students' access, teachers' preparedness, the development of digital skills, and strategies for incorporating ICT into the curriculum.

Many critical factors must be considered for successful online education in South Africa. According to Mpungose (2020), one of the most significant issues is the digital divide, defined as the difference in the accessibility of computers and the internet. This inequality is a significant roadblock to online education's potential in South Africa. Furthermore, the country's educational system has transitioned digitally because of the COVID-19 epidemic (Mhlanga & Moloi, 2020). Many people have the wrong idea about what it means to be a "digital native." However, research out of South Africa found that students' actual tech use is more affected by their level of expertise and familiarity with various forms of information and communication technology than by their chronological age (Brown & Czerniewicz, 2010). South Africa's low smartphone penetration and lack of technical knowledge are important impediments to its digital entrepreneurship, which is still in its early phases (Cobo & Rankhumise, 2022). Mhlanga et al. (2022) list historical inequality and the digital divide as two of the many barriers to online education in the country. To address these concerns, it is recommended that digital pedagogy and online learning platforms be integrated into South Africa's university system (Woldegiorgis, 2022). Suppose e-learning initiatives in South Africa are to succeed in bridging the income gap and the digital divide. In that case, increasing public understanding of the need for digital literacy is essential. Recently, this was brought to light by Mphahlele, Seeletso, Muleya, and Simui (2021). Balogun and Kalusopa (2021) and Masenya and Ngulube (2020) argue that the nation's academic institutions should lead in establishing digital preservation standards, regulations, and procedures to ensure digital resources last a long time. Lastly, as Raaff, Rothwell, and Wynne (2022) pointed out, connecting data and cloud policies with laws such as the PoPI Act is crucial for boosting digital infrastructure, digital skills, and South Africa's digital economy. The effectiveness of digital learning in South Africa depends on closing the digital divide, increasing digital literacy, fostering digital entrepreneurship, and establishing stringent data preservation methods.

Several important strategies may be implemented to make online education more sustainable in the long run. One practical approach is to update teacher competency frameworks to address the challenges of the present. Basilotta-Gómez-Pablos et al. (2022) and Caena and Redecker (2019) state that teachers must improve their digital talents to be

effective in today's digital environment. It is also essential to include sustainability concepts in online teaching. To this end, Xiang et al. (2020) propose an all-encompassing approach to teaching digital design that considers environmental factors. Training for IT professionals' integration may be successfully boosted by a hybrid strategy incorporating workshops, curricular examples, and a peer-support system (Tokovska et al., 2022). It is critical to provide technological resources, pedagogical advice, and policy considerations for sustainable digital teaching practices to prioritise the development of teaching staff's digital literacy (Akil & Adnan, 2022). According to Jääskä et al. (2021), educational games may be used in digital teaching to enhance student engagement and participation in the learning process. Another way to make digital teaching practices last longer is to change college courses so they teach skills related to sustainable development (Schweizer et al., 2019). In addition to fostering sustainable digital teaching, the Open Science (OS) and Open Educational Practices (OEP) frameworks may tackle important issues in educational action research (Czerwonogora & Rodés, 2019).

Building cooperative academic interactions and fostering mutually beneficial linkages across institutions is crucial for successfully implementing sustainable development concepts in higher education (Makarova & Wang, 2020). Adopting these strategies can help higher education institutions improve the digital teaching practices' sustainability, increase teachers' digital competencies, incorporate sustainability principles into their lessons, and cultivate a culture of collaboration and ongoing professional development in the digital education field. According to Joutsenlahti and Perkkilä (2019), South African schools must incorporate sustainable development principles into mathematics education so that students can be prepared to deal with the challenges posed by the Fourth Industrial Revolution (4IR) and have the skills they need to help build a sustainable future. To guarantee the effective adoption of digital learning at SA's tertiary institutions, it is crucial to think about what works.

Enhancing digital education in higher education requires a strategic approach to effectively leveraging technology for improved learning outcomes. To empower learners, teachers must develop competencies aligned with 21st-century challenges. Implementing frameworks like the European Digital Competence Framework for Educators can enhance digital teaching practices (Caena & Redecker, 2019). Fostering digital literacy among teaching staff and students is essential. Strategies such as training programs, awareness campaigns, and infrastructure enhancement can improve digital literacy levels (Matriano, 2023; Razak et al., 2022). Incorporating educational games into the curriculum can enhance student engagement, critical thinking skills, and overall learning experiences (Holbrey, 2020; Bakhsh et al., 2022). Redesigning higher education curricula to include digital literacy components and promote competencies for sustainable development can enhance digital education practices. Professional development programs focused on digital literacy and personalised learning can empower educators to enhance digital teaching practices (Hobbs & Coiro, 2018). By incorporating community-based strategies and programs that advocate for digital literacy, a supportive environment can be created to enhance digital education (Abiddin et al., 2022). Using location-based mobile learning games may enhance higher education courses by including new and interesting instructional experiences (Edmonds & Smith, 2017). To enhance digital education practices, inclusive frameworks for digital literacy that empower learners, increase well-being, and limit the danger of exploitation is essential (Nedungadi et al., 2018). By following these principles, HEIs may empower instructors, foster digital literacy, and build inclusive learning environments that use technology to enhance educational results.

THEORETICAL FRAMEWORK

Wenger expanded upon the work of Lave and Wenger (1991) in his 1998 work on the Community of Practice (CoP) theory of social learning. Wenger says learning involves community, identity, purpose, and practice. He introduces related concepts as he discusses these four learning areas. Wenger says Joint Enterprise, Mutual Engagement, and Shared Repertoire define a community's practice. Sharing goals, interests, and possessions may define the community. Participation creates new engagement, innovation, and harmonious identities among community members. Imagination is the ability to generate mental images of the world and discern connections across time and place by extrapolating from one's experiences. In contrast, engagement is active involvement in reciprocal meaning negotiation. Coordinating efforts so that they fit into larger organisations and contribute to larger companies is what we mean when we talk about alignment. Wenger goes on to say that practice is about more than just doing; it is also about doing it inside a social and historical framework that provides meaning and structure. Norms and expectations on the how and what of doing things contribute to the gradual development of a CoP. As a result, knowing the "ways of doing" or social norms of a particular CoP is essential for joining that CoP.

The theory of Community of Practice (CoP) emphasises the pivotal role of community in the learning process. According to Graven and Lerman (2003), the community is central to analysing this theory. It underscores the significance of individual experiences within these communities, as Wenger (2009) noted. This implies that learning is shaped and defined by the community. Virtual Communities of Practice (VCoPs) is a concept that revolves around the theory of CoP, where members engage in online discussions and share knowledge to learn and exchange insights in a digital environment. VCoPs are increasingly recognised as valuable platforms for collaborative learning within workplaces, enabling members to co-create knowledge and enhance their professional development. The theory emphasises overcoming knowledge-sharing barriers and fostering collaboration within VCoPs. VCoPs aim to supplement face-to-face interactions, facilitate collaboration, and enhance members' knowledge-sharing by utilising social media technologies and online communication tools. Furthermore, the theory highlights the importance of structuring

characteristics and intentional formation of VCoPs to ensure their development and sustainability. Establishing multi-disciplinary VCoPs can facilitate knowledge exchange and expertise sharing within professional networks and organisations. Moreover, the virtual community of practice theory highlights the importance of a non-hierarchical, participatory, and dynamic learning model within VCoPs to foster effective knowledge exchange and collaboration. VCoPs can establish inclusive and stimulating environments for members by implementing creative learning techniques and providing dedicated participation time (Struminger, Arora, Zalud-Cerrato, Lowrance & Ellerbrock 2017). Essentially, the theory emphasises the significance of VCoPs as collaborative learning platforms, promoting knowledge sharing, professional development, and meaningful interactions in digital spaces. With intentional structuring, overcoming knowledge-sharing barriers, and cultivating a collaborative culture, organisations can maximise the potential of virtual communities to enhance learning outcomes and facilitate valuable member interactions.

METHODOLOGY

When conducting education research, researchers often gather second-hand information through various methods such as surveys, interviews, or observations. Urhahne's (2018) research highlights the significance of recognising the nuances of data collection in educational psychology and outlines various methods for collecting primary and secondary education data. Conversely, Smith (2008) emphasises that secondary data analysis involves examining existing data sources to generate new insights or validate findings. Smith also notes the underutilisation of this approach in education and social sciences. Furthermore, Pandya and Shah (2018) suggest a framework for measuring innovative behaviour by combining primary data collected through interviews with secondary data obtained through a literature review. The integration of primary and secondary data sources demonstrates the complementary nature of these approaches in educational research. Primary data offers first-hand insights, while secondary data provides a broader context and validation for research findings. In this study, the researcher utilised information from several secondary sources, including published and peer-reviewed journals and other relevant web sources. The researcher used search engines such as Google Scholar, IBSS, and Scopus to gather relevant publications for our study. We carefully selected publications that met strict inclusion and exclusion criteria, ensuring their pertinence to the subject matter. Each article was thoroughly evaluated, and only those deemed highly relevant were included in the selection process. Out of the 53 articles found, we discovered 30 publications related to our research topic, with 10 being particularly effective in addressing our objective. Secondary data can adhere to professional guidelines unavailable to individual researchers or small research projects. Secondary studies form a comprehensive whole by combining published research on a specific topic. Collecting and analysing data from various sources can benefit users and be tailored to individual needs (Prasanna, 2022).

In their recent study, Herne et al. (2022) explore how the impartiality of argument sources affects the evaluation of political arguments. They find that thoughtfully incorporating secondary materials can lead to the development of original ideas in research. In fact, by integrating existing knowledge and insights from secondary sources, researchers can build upon established foundations to generate new perspectives and innovative solutions. Rietzschel et al. (2010) also emphasise the importance of selecting creative ideas based on their originality and impact, calling for a balance between creativity and effectiveness in idea selection. This highlights the potential of secondary materials to identify original and impactful ideas. Moreover, Clauset et al. (2015) discuss how ideas from different institutional backgrounds can influence their spread within academic networks, underscoring the significance of considering diverse perspectives from secondary sources. By drawing upon a wide range of secondary materials, researchers can expose themselves to varied viewpoints and insights, leading to innovative ideas. Finally, Reiter-Palmon et al. (2019) provide a systematic framework for scoring divergent thinking tests, emphasising originality as a key dimension of creativity. This underscores the value of incorporating secondary data to assess and enhance the originality of ideas in research. Researchers can strive to produce more original and impactful contributions without sacrificing effectiveness by leveraging secondary materials to understand existing frameworks and dimensions of creativity.

Table 1 A summary of the articles that were reviewed

Author/s	The title of the article	Aim of the article
1. Nouh Alhindawi	E-Learning Innovation in the Institutions of Jordan's Higher Education: A Case Study	This paper aims to provide an overview of e-learning innovation in Jordan's higher education institutions, including the benefits and challenges of e-learning and the role of the Ministry of Higher Education and Scientific Research in supporting its development.
2. Jayaluxmi Naidoo & Sarasvathie Reddy	Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods	This study aimed to explore participants' experiences, views, implications, and suggestions for technology-based teaching methods for mathematics.
3. Aulia Kirana Hapsari & Deshinta Puspa Ayu Dwi Argaswari	Mathematics Teaching Anxiety of Indonesian Elementary School Teachers in Online Learning During COVID-19 Outbreak	This study aims to identify the scale of mathematics teaching anxiety among elementary teachers during online learning during the COVID-19 pandemic in the Pekayon district and determine the mathematics anxiety in teaching during the pandemic.

4. Luis Silva Rodrigues & Politécnico do Porto	Challenges of Digital Transformation in Higher Education Institutions: A Brief Discussion	The aim is to discuss the main challenges of digital transformation in HEIs.
5. Mamdouh Alenezi	Deep Dive into Digital Transformation in Higher Education Institutions	The paper aims to delineate the challenges higher education institutions face in pursuit of digital transformation.
6. Víctor J. García-Morales, Aurora Garrido-Moreno & Rodrigo Martín-Rojas	The Transformation of Higher Education After the COVID Disruption: Emerging Challenges in an Online Learning Scenario	The paper aims to explain some barriers and challenges that universities encounter and the technological resources and methodologies they have used in the current scenario to transform higher education and face challenges.
7. Nguyen Thi Huong Giang, Pham Thi Thanh Hai, Nguyen Thi Thanh Tu & Phan Xuan Tan	Exploring the Readiness for Digital Transformation in a Higher Education Institution Towards Industrial Revolution 4.0	This study aims to analyse the characteristics of the digital university model to identify the criteria for assessing the availability of the digital transformation process.
8. Jayaluxmi Naidoo & Sarasvathie Reddy	Embedding Sustainable Mathematics Higher Education in the Fourth Industrial Revolution Era Post-COVID-19: Exploring Technology-Based Teaching Methods	This study aimed to explore participants' experiences, views, implications and suggestions for technology-based teaching methods for mathematics.
9. Silvia Farias-Gaytan, Ignacio Aguaded & Maria-Soledad Ramirez-Montoya	Digital transformation and digital literacy in the context of complexity within higher education institutions: a systematic literature review	This research aimed to identify studies related to digital transformation and digital literacy in higher education institutions through a systematic literature review.
10. Maria José Sá & Sandro Serpa	The COVID-19 Pandemic as an Opportunity to Foster the Sustainable Development of Teaching in Higher Education	This perspective paper aims to add to the knowledge already produced on this topic by arguing that these challenging conditions can be a pivotal moment of opportunity for reshaping higher education through the implementation, development, and diffusion of digital technologies among academics and students.

The results were obtained based on the reviewed articles

As indicated before, all of the claims and suggestions made in this piece came from secondary sources. In 2023, Alhindawi conducted research that found that many universities employ eLearning. This study looked upon those results. However, many eLearning programmes did not work together or adhere to standards, and there was insufficient infrastructure, training, and support for students and teachers. The research also found that infrastructure and resource availability, eLearning content quality and relevance, and staff and student support and training affect eLearning readiness. While online chats and multimedia learning materials showed the most impact, the study found that eLearning generally enhanced student learning.

Naidoo and Reddy researched the subject of long-term maths education in the Fourth Industrial Revolution (4IR) age after COVID-19 in 2023. The research found that maths education, assessment, and learning improved through online teaching approaches promoting social engagement and community presence. The results are consistent with what is predicted by the CoI and SAMR models. The instructor's virtual presence also allowed for establishing a safe classroom setting, which facilitated the use of technology in the classroom and revolutionised conventional teaching methods. Regarding improving online instruction, the SAMR and CoI frameworks stress the need for instructor presence. The research also found that using technology in the classroom improved students' ability to think critically about mathematics and sparked deeper involvement via class discussions and debates about different problem-solving approaches. If we are serious about revolutionising education, we must use strategies encouraging cognitive presence. This is borne out by the suggestions made by the SAMR and CoI frameworks. Participant receptivity to technology-based pedagogical approaches was also shown to be impacted by participants' prior educational experiences. Those who participated in the study felt that pupils will continue to reap the benefits of technology in the classroom even after the COVID-19 epidemic, particularly in the Fourth Industrial Revolution (4IR) period. Incorporating lessons learnt during the epidemic into future teaching practices is crucial, and this study emphasises the sustainability of technology-based teaching techniques in mathematics education.

Hapsari and Argaswari (2022) looked at how primary school math instructors in Indonesia felt about teaching math during the COVID-19 outbreak and how online learning affected their concerns. Teachers reported significant levels of anxiety, which was linked to Student-Directed Mathematics Teaching Anxiety, according to the data. Nonetheless, online lesson plans and delivery were drastically different for instructors reporting high, low, or average levels of anxiety. Concerns about students' knowledge of the content, technological difficulties, and limited media and internet access were among the most often cited causes of moderate concern among educators in this setting. Educators who report a moderate degree of anxiety often, though not always without sacrifice, seek out a variety of subject-aligned online instructional resources. Even though instructors have access to many online resources and have attended seminars regarding online

learning, they are still worried that children will not be able to understand the maths taught this way. According to research by Mamdouh in 2021, a significant problem in universities is that professors do not know anything about computers. Higher education institutions must adopt new pedagogical practices and technological resources like online video conferencing, learning simulations, and collaborative projects to remain competitive in the face of rapid global change. However, institutions often have trouble determining the ROI of these expenditures and their financial case, especially regarding fundamental digital skills. Improving the student experience, leading to greater enrolment, retention, and on-time graduation rates, is one example of an activity that is slowly developing or challenging to measure, but it is crucial to consider. Another example is saving money and time for faculty via more efficient operations and automation. Organisations have been compelled to adopt digital tools and technology because of the COVID-19 pandemic. This is to ensure that they can adapt to the changing conditions.

Victor, García-Morales, Garrido-Moreno, and Martín-Rojas (2021) suggest that the COVID-19 epidemic and digital technology provide a unique global opportunity to improve higher education. Online experiences have transformed higher education, and even after COVID-19, online teaching is crucial. Our research supports using web-based learning platforms, video-conferencing tools, MOOCs, streaming conferences, instant messaging tools, educational apps, and other technological resources for online learning. With these instruments' help, new education approaches have become possible. Nevertheless, stakeholders faced several challenges adjusting to the new setting due to the sudden and coerced shift to online learning. Another major roadblock to technical progress is the human element. Faculty, students, and technical staff must all be involved in the transformation process, which can only be achieved with the assistance and guidance of the institution's leadership.

According to research by Nguyen, Pham, Nguyen, and Phan (2021), faculty members with advanced degrees are more inclined to understand the significance of digital transformation in schools. By showcasing the advantages of digital technology in delivering training, instruction, and administrative services at the university level, this group will be instrumental in advocating for and carrying out digital transformation in educational institutions. We have determined that in order for higher education institutions to establish core values amid digital transformation, four critical factors—the Education Programme, the Learners, the Training Services, and Governance—must undergo fundamental changes based on the responses of faculty and students to our survey about HUST's readiness for digital transformation. Improving the effectiveness and efficiency of universities in the era of the fourth industrial revolution is the goal of this value chain. According to the research, digital technology in the classroom affects many different parts of a school's ecology. Research into the reviewed literature has shown that there has been a rise in funding for information and communication technology (ICT) interventions that aim to improve literacy, STEM (science, technology, engineering, and mathematics) education, and science and mathematics education in particular. These interventions are often based on findings from national assessments. Research in fields outside of education, such as social studies, was scant.

Research on digital literacy and digital transformation within the complex environment of higher education institutions was carried out in 2020 by Farias-Gaytan, Aguaded, and Maria-Soledad Ramirez-Montoya. According to their results, educational institutions are more interested in using technology for instructional reasons. However, they also noted that establishing digital competencies for students and instructors is challenging. Among the intriguing findings of the research is the need for a guiding framework to help higher education institutions traverse the many aspects influencing digital transformation, as well as the apparent absence of focus on media literacy. According to José Sá and Serpa's study on the effects of COVID-19, education must be reinvented in light of the pandemic. They also found that there must be sustained digital development in teaching. The research concludes that one must overcome significant obstacles to succeed in the global education industry.

Public intervention and funding for education, especially at the university level, are urgently needed, according to a new study on the effects of digitalisation on higher education within the framework of sustainable development and the COVID-19 pandemic (Toader, Safta, Titiris, Firtescu, 2021). The economics literature consistently states that higher education contributes to economic growth and sustainable development. The authors argue that E-learning and digitalisation should be the top priorities of public education policy, with increasing public spending laying the groundwork for sustainable growth. Researchers also discovered that most instructors and students depended on their own devices and subscriptions regarding online class activities. The course delivery, student access to resources and materials, assignment submission, and evaluation are all made much easier using online platforms, essential to online and hybrid university education.

RECOMMENDATIONS

Alhindawi (2023) proposed ways to improve teacher education and professional development by implementing policies and guidelines for eLearning, including standards for online course development and student engagement expectations. Teachers and students can benefit from workshops and support using technology and infrastructure upgrades such as hardware, software, and internet connectivity. Increased funding and partnerships with government agencies, educational organisations, and industry partners can improve eLearning quality. To enhance digital mathematics teaching and learning in South African higher education institutions, strategies based on research findings should be implemented, including faculty grants for developing new teaching technologies and CPD for improved outcomes. Teaching students practical negotiation skills, embracing digital education, and pushing their digital narratives further in the post-COVID era is essential. Despite challenges, higher education institutes can compete with other industries and businesses by prioritising

digital transformation. Integrating Information Communication Technology (ICT) in education has been identified as a strategy to enhance mathematics achievement among South African students (Saal & Graham, 2019). Additionally, the adoption of Technology-enhanced learning (TEL) and Digital Game-based Learning (DGBL) can further enhance mathematics education in universities (Mamotheti & Daramola, 2022). Emergency remote teaching (ERT) and the use of digital platforms for learning mathematics have been given more importance due to the COVID-19 pandemic, which has sped up the digital transformation of education in South Africa (Chisita & Chizoma, 2021; Chirinda et al., 2022; Naidoo, 2020). Moreover, academic institutions must ensure the safety of their digital resources after the digital revolution. This calls for digital preservation techniques to oversee institutional repositories (Luthuli, 2023; Masenya & Ngulube, 2019). To improve mathematics teaching, it is essential to enhance teachers' mathematical knowledge through interventions and professional development programs (Ige & Jita, 2020; Jita & Ige, 2019; Ramaila & Seloane, 2020). There may be advantages to using technology in mathematics education, as student opinions of computer-assisted learning have been good (Hartley & Treagust, 2014). Mathematics education in South Africa may also benefit from considering students' actual classroom settings when designing lessons (Kotze & Strauss, 2006). Ultimately, South Africa can successfully revolutionise and maintain digital mathematics education at universities by enhancing teacher preparation, incorporating technology into the classroom, using online platforms for learning, and protecting digital assets. According to studies, these initiatives can potentially improve mathematical education results and increase digital literacy in South African schools.

CONCLUSION

In conclusion, academic institutions in South Africa need to implement a comprehensive plan to enhance digital mathematics teaching and learning. Improving teacher training, integrating technology into education, using digital platforms for learning, and protecting digital materials are all essential methods recommended by research. Amidst the rapid digitalisation of education brought about by the COVID-19 epidemic, the significance of emergency remote teaching and digital platforms for mathematics instruction has been brought to light. Additionally, addressing contextual factors in the mathematics learning environment and improving teachers' mathematical knowledge are crucial for enhancing mathematics education outcomes. To further improve digital mathematics instruction and learning, relevant research recommends rethinking strategies to enhance student learning and engagement, increasing funding for education resources, aligning curricula with societal needs, and developing digital competencies in higher education institutions. Additionally, bridging the digital divide, encouraging technology-enabled teaching and learning, and promoting sustainable practices through technology are essential for long-term success. The COVID-19 epidemic has taught us that universities must embrace digital transformation, blended learning, and online instruction on an ongoing basis. Colleges and universities in South Africa stand to gain by embracing digital transformation, funding professional development for teachers, and finding innovative ways to use technology in mathematics curricula. By taking a comprehensive approach to addressing the challenges and opportunities presented by digitalisation, South Africa can advance digital mathematics instruction and learning, ultimately improving educational outcomes and promoting digital literacy in higher education.

REFERENCES

11. Abiddin, N. Z., Ibrahim, I., & Abdul Aziz, S. A. (2022). Non-governmental organisations (NGOs) and their part towards sustainable community development. *Sustainability*, *14*(8), 4386. https://doi.org/10.3390/su14084386.
12. Akil, W. F. H. W. M., & Adnan, A. (2022). Promoting digital literacy in higher education: A case study of a medical laboratory program in Malaysia. *International Journal of Academic Research in Progressive Education and Development*, *11*(4), 735-755. http://dx.doi.org/10.6007/IJARPED/v11-i4/15906.
13. Alenezi, M. (2021). Deep dive into digital transformation in higher education institutions. *Education Sciences*, *11*(12), 770.https://doi.org/10.3390/educsci11120770.
14. Alhindawi, N. (2023). E-Learning innovation in the institutions of Jordan's higher education: a case study. *International Journal of Applied Mathematics and Information Sciences (AMIS)*, *17*(2), 273-283.http://dx.doi.org/10.18576/amis/170210.
15. Alonso-García, S., Aznar-Díaz, I., Caceres-Reche, M. P., Trujillo-Torres, J. M., & Romero-Rodríguez, J. M. (2019). Systematic review of good teaching practices with ICT in Spanish higher education. Trends and challenges for sustainability. *Sustainability*, *11*(24), 7150. https://doi.org/10.3390/su11247150.
16. Ardichvili, A. (2008). Learning and knowledge sharing in virtual communities of practice: Motivators, barriers, and enablers. *Advances in developing human resources*, *10*(4), 541-554. https://doi.org/10.1177/1523422308319536.
17. Armoed, Z. (2021, February). The Covid-19 pandemic: Online teaching and learning at higher education institutes. In *IOP Conference Series: Earth and Environmental Science* (Vol. 654, No. 1, p. 012026). IOP Publishing. https://doi.org/10.1088/1755-1315/654/1/012026.
18. Bakhsh, K., Hafeez, M., Shahzad, S., Naureen, B., & Faisal Farid, M. (2022). Effectiveness of digital game-based learning strategy in Higher Educational Perspectives. *Journal of Education and E-learning Research*, *9*(4), 258-268. https://doi.org/10.20448/jeelr.v9i4.4247.
19. Bakry, D., Dabab, M., & Khalifa, R. (2019, August). Reflection of critical thinking on the sustainable educational development: A case study of the Middle East and North Africa. In *2019 Portland International Conference on*

Management of Engineering and Technology (PICMET) (pp. 1-11). IEEE. https://doi.org/10.23919/PICMET.2019.8893834.
20. Balogun, T., & Kalusopa, T. (2021). A framework for digital preservation of Indigenous knowledge system (IKS) in repositories in South Africa. *Records Management Journal*, *31*(2), 176-196. https://doi.org/10.1108/RMJ-12-2020-0042.
21. Balogun, A.L., Marks, D., Sharma, R., Shekhar, H., Balmes, C., Maheng, D., Arshad, A. and Salehi, P., (2020). Assessing the potential of digitalisation as a tool for climate change adaptation and sustainable development in urban centres. *Sustainable Cities and Society*, *53*, p.101888. https://doi.org/10.1016/j.scs.2019.101888.
22. Balyer, A., & Öz, Ö. (2018). Academicians' Views on Digital Transformation in Education. *International Online Journal of Education and Teaching*, *5*(4), 809-830. *http://iojet.org/index.php/IOJET/article/view/441/295*.
23. Banerjee, M. (2021). *Teacher Professional Development for the Digital Age: Making Technology Integration Possible* (Doctoral dissertation). https://hdl.handle.net/1969.1/195270.
24. Barakabitze, A. A. (2014). The Context of Education Initiatives, Importance and Inhibitors of ICTs towards improving teaching and learning in Tanzania: A Critical Literature review.
25. Barakabitze, A. A., Kitindi, E. J., Sanga, C., Kibirige, G., & Makwinya, N. (2015). Exploring students' skills and attitudes on using ICTs effectively: A case study of selected Tanzanian public secondary schools. *Universal Journal of Educational Research*, *3*(6), 407-425. https://doi.org/10.13189/ujer.2015.030609.
26. Barnett, B. G., Shoho, A. R., & Okilwa, N. S. (2017). Assistant principals' perceptions of meaningful mentoring and professional development opportunities. *International Journal of Mentoring and Coaching in Education*, *6*(4), 285–301. https://doi.org/10.1108/IJMCE-02-2017-0013.
27. Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L. A., & Otto, A. (2022). Teachers' digital competencies in higher education: a systematic literature review. *International Journal of Educational Technology in Higher Education*, *19*(1), 8. https://doi.org/10.1186/s41239-021-00312-8.
28. Basnet, B. B., Bishwakarma, K., Pant, R. R., Dhakal, S., Pandey, N., Gautam, D., ... & Basnet, T. B. (2021). Combating the COVID-19 pandemic: experiences of the first wave from Nepal. *Frontiers in Public Health*, *9*, 613402. https://doi.org/10.3389/fpubh.2021.613402.
29. Brown, C., & Czerniewicz, L. (2010). Debunking the 'digital native': Beyond digital apartheid, towards digital democracy. *Journal of computer-assisted learning*, *26*(5), 357-369. https://doi.org/10.1111/j.1365-2729.2010.00369.x.
30. Cachia, R., Chaudron, S., Di Gioia, R., Velicu, A., & Vuorikari, R. (2021). Emergency remote schooling during COVID-19, a closer look at European families. https://ketlib.lib.unipi.gr/xmlui/handle/ket/3765.
31. Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st-century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu). *European journal of education*, *54*(3), 356-369. https://doi.org/10.1111/ejed.12345.
32. Clauset, A., Arbesman, S., & Larremore, D. B. (2015). Systematic inequality and hierarchy in faculty hiring networks. *Science advances*, *1*(1), e1400005. https://doi.org/10.1126/sciadv.1400005.
33. Chirinda, B., Ndlovu, M., & Spangenberg, E. (2021). Teaching mathematics during the COVID-19 lockdown in a context of historical disadvantage. *Education Sciences*, *11*(4), 177. https://doi.org/10.1016/j.compedu.2020.104080.
34. Costa, P., Castaño-Muñoz, J., & Kampylis, P. (2021). Capturing schools' digital capacity: Psychometric analyses of the SELFIE self-reflection tool. *Computers & Education*, *162*, 104080. https://doi.org/10.1016/j.compedu.2020.104080.
35. Cranfield, D., Venter, I., Tick, A., Blignaut, R., & Renaud, K. (2023). 'THE E-LEARNING QUAGMIRE OF COVID-19: AN ACADEMIC PERSPECTIVE. In *INTED2023 Proceedings* (pp. 4716-4725). IATED. https://doi.org/10.21125/inted.2023.1233.
36. Czerwonogora, A., & Rodés Paragarino, V. (2019). PRAXIS: Open educational practices and open science to face the challenges of critical educational action research. *Open Praxis*. http://repositorio.cfe.edu.uy/handle/123456789/1028.
37. Damani, K., Daltry, R., Jordan, K., Hills, L., & Evans, L. (2022). EdTech for Ugandan girls: Affordances of different technologies for girls' secondary education during the COVID-19 pandemic. *Development Policy Review*, *40*, e12619. https://doi.org/10.1111/dpr.12619.
38. Daniel, S. J. (2020). Education and the COVID-19 pandemic. *Prospects*, *49*(1), 91-96. https://doi.org/10.1007/s11125-020-09464-3.
39. Darling-Hammond, L. (2017). Teacher education around the world: What can we learn from international practice? *European journal of teacher education*, *40*(3), 291-309. https://doi.org/10.1080/02619768.2017.1315399.
40. Delima, D. A., Mamaril, R. J., Javier, D. R. C., Dela Peña, M. O., Soriano, R. F., & Ladjammah, K. S. J. (2022). Awareness of senior high school students on digital literacy skills: A qualitative study. *Sinaya: A Philippine Journal for Senior High School Teachers and Students*, *1*(3), 2. https://doi.org/10.59588/3027-9283.1048.

41. Delcker, J., & Ifenthaler, D. (2021). Teachers' perspective on school development at German vocational schools during the Covid-19 pandemic. *Technology, Pedagogy and education*, *30*(1), 125-139. https://doi.org/10.1080/1475939X.2020.1857826.
42. de Sousa, L. O. (2021). Learning experiences of a participatory approach to educating for sustainable development in a South African higher education institution yielding social learning indicators. *Sustainability*, *13*(6), 3210. https://doi.org/10.3390/su13063210.
43. Dubé, L., Bourhis, A., & Jacob, R. (2005). The impact of structuring characteristics on the launching of virtual communities of practice. *Journal of Organisational Change Management*, *18*(2), 145-166. https://doi.org/10.1108/09534810510589570.
44. Edmonds, R., & Smith, S. (2017). From playing to designing: Enhancing educational experiences with location-based mobile learning games. *Australasian Journal of Educational Technology*, *33*(6). https://doi.org/10.14742/ajet.3583.
45. Elfert, M. (2019). Lifelong Learning in Sustainable Development Goal 4: What does it mean for UNESCO's rights-based approach to adult learning and education? *International Review of Education*, *65*(4), 537-556. https://doi.org/10.1007/s11159-019-09788-z.
46. Estermann, T., Bennetot Pruvot, E., Kupriyanova, V., & Stoyanova, H. (2020). The impact of the Covid-19 crisis on university funding in Europe. *European University Association asbl: Brussels, Belgium*.
47. Gaol, F. L., & Prasolova-Førland, E. (2022). Special section editorial: The frontiers of augmented and mixed reality in all levels of education. *Education and Information Technologies*, 1-13. https://doi.org/10.1007/s10639-021-10746-2.
48. Gendron, Y., Paugam, L., & Stolowy, H. (2023). Breaking incommensurability boundaries? On the production and publication of inter-paradigmatic research. *Qualitative Research in Accounting & Management*, *20*(5), 675-694. https://doi.org/10.1108/qram-09-2022-0147
49. Govender, R., & Mpungose, C. (2022). Lecturers' technostress in the coronavirus (COVID-19) context at a South African university. *Cogent Education*, *9*(1), 2125205. https://doi.org/10.1080/2331186X.2022.2125205.
50. Graven, M., & Lerman, S. (2003). Wenger, E. (1998). Communities of practice: Learning, meaning and identity.
51. Hapsari, A. K., & Argaswari, D. P. A. D. (2022). Jurnal Pendidikan MIPA. *Jurnal Pendidikan*, *23*(2), 595-605. http://jurnal.fkip.unila.ac.id/index.php/jpmipa/
52. Herne, K., Sipinen, J., Kestilä-Kekkonen, E., Mattinen, L., & Söderlund, P. (2022). The force of the argument source: The partiality of the source influences the evaluation of political arguments. *Frontiers in Communication*, *7*, 778771. https://doi.org/10.3389/fcomm.2022.778771.
53. Hlatshwayo, M. C. (2019). *Adoption of Mobile Learning at the University of Technology in South Africa* (Master's thesis, Vaal University of Technology (South Africa)).
54. Hobbs, R., & Coiro, J. (2019). Design features of a professional development program in digital literacy. *Journal of Adolescent & Adult Literacy*, *62*(4), 401-409. https://doi.org/10.1002/jaal.907.
55. Holbrey, C. E. (2020). Kahoot! Using a game-based approach to blended learning to support effective learning environments and student engagement in traditional lecture theatres. *Technology, Pedagogy and Education*, *29*(2), 191-202. https://doi.org/10.1080/1475939X.2020.1737568.
56. Hornberger, N. H. (2020). Reflect, revisit, reimagine: Ethnography of language policy and planning. *Annual Review of Applied Linguistics*, *40*, 119-127. https://doi.org/10.1017/S026719052000001X.
57. Indicators, O. E. C. D. (2023). Education at a Glance 2022. *link]. Acesso em março de*.
58. Ibrahim, S., & Purnama, H. (2023). Withdrawn: Transformation of the Indonesian Government Bureaucracy. https://doi.org/10.31014/aior.1991.06.02.407.
59. Isabirye, A. K., & Dlodlo, N. (2014). Perceived inhibitors of innovative E-learning teaching practice at a South African university of technology. *Mediterranean Journal of Social Sciences*, *5*(4), 390-398. https://doi.org/10.5901/mjss.2014.v5n4p390.
60. Jääskä, E., Aaltonen, K., & Kujala, J. (2021). Game-based learning in project sustainability management education. *Sustainability*, *13*(15), 8204. https://doi.org/10.3390/su13158204.
61. Joutsenlahti, J., & Perkkilä, P. (2019). Sustainability Development in Mathematics Education—A Case Study of What Kind of Meanings Do Prospective Class Teachers Find for the Mathematical Symbol "2 3"? *Sustainability*, *11*(2), 457. https://doi.org/10.3390/su11020457.
62. Kille, T., Bates, P., & Murray, P. S. (2015). Peer observation in the online learning environment: the case of aviation higher education. In *Teaching for Learning and Learning for Teaching: Peer Review of Teaching in Higher Education* (pp. 79-97). Rotterdam: Sense Publishers.
63. Kizito, R., Munyakazi, J., & Basuayi, C. (2016). Factors affecting student success in a first-year mathematics course: a South African experience. *International Journal of Mathematical Education in Science and Technology*, *47*(1), 100-119. https://doi.org/10.1080/0020739X.2015.1057247.
64. Klement, M., Dostál, J., Bártek, K., & Gregar, J. (2017). *Perception and Possibilities of ICT Tools in the Education from the Teachers' Perspective*. Palacký University Olomouc. https://doi.org/10.5507/pdf.17.24450933.

65. Krmac, N. (2022). Interpretive Research and its Use in the Field of Pedagogy. *Revija za Elementarno Izobraževanje*, *15*(2), 261-284. https://doi.org/10.18690/rei.15.2.261-284.2022.
66. Kulikowski, K., Przytula, S., & Sulkowski, L. (2021). Emergency forced pandemic e-learning–feedback from students for HEI management. *Open Learning: The Journal of Open, Distance and e-Learning*, *36*(3), 245-262. https://doi.org/10.1080/02680513.2021.1942810.
67. Lavidas, K., Apostolou, Z., & Papadakis, S. (2022). Challenges and opportunities of mathematics in digital times: Preschool teachers' views. *Education Sciences*, *12*(7), 459. https://doi.org/10.3390/educsci12070459.
68. Leal Filho, W., Raath, S., Lazzarini, B., Vargas, V. R., de Souza, L., Anholon, R., ... & Orlovic, V. L. (2018). The role of transformation in learning and education for sustainability. *Journal of cleaner production*, *199*, 286-295. https://doi.org/10.1016/j.jclepro.2018.07.017.
69. Lei, X., Shen, Z. Y., Štreimikienė, D., Baležentis, T., Wang, G., & Mu, Y. (2024). Digitalisation and sustainable development: Evidence from OECD countries. *Applied Energy*, *357*, 122480. https://doi.org/10.1016/j.apenergy.2023.122480.
70. Lembani, R., Gunter, A., Breines, M., & Dalu, M. T. B. (2020). The same course, different access: the digital divide between urban and rural distance education students in South Africa. *Journal of geography in higher education*, *44*(1), 70-84. https://doi.org/10.1080/03098265.2019.1694876.
71. Liebenberg, J., Mentz, E., & Breed, B. (2012). Pair programming and secondary school girls' enjoyment of programming and the subject of Information Technology (IT). *Computer Science Education*, *22*(3), 219-236. https://doi.org/10.1080/08993408.2012.713180.
72. Luong, J., & Arnold, R. (2020, December). Creating a digital learning community: Four key considerations for remote learning during a pandemic. In *2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 786-791). IEEE. https://doi.org/10.1109/TALE48869.2020.9368385.
73. Mahabeer, P., & Pirtheepal, T. (2019). Online formative assessment tools: lecturers' experiences using Moodle at a university in South Africa. *Journal of Educational Studies*, *18*(1), 43–63. https://hdl.handle.net/10520/EJC-1d876408e3.
74. Masenya, T. M., & Ngulube, P. (2020). Adoption and implementation of digital preservation strategies by academic libraries in South Africa. *Mousaion*, *38*(1). https://hdl.handle.net/10520/EJC-1e3f2c4f45.
75. Mhlanga, D., & Moloi, T. (2020). COVID-19 and the digital transformation of education: What are we learning on 4IR in South Africa? *Education sciences*, *10*(7), 180. https://doi.org/10.3390/educsci10070180.
76. Matlala, M. E., Ncube, T. R., & Parbanath, S. (2022). The state of digital records preservation in South Africa's public sector in the 21st century: a literature review. *Records Management Journal*, *32*(2), 198-212. https://doi.org/10.1108/RMJ-02-2021-0004.
77. Matriano, M. T. (2023). Balancing of skills in the digital transformation of education and employability. In *SHS Web of Conferences* (Vol. 156, p. 08004). EDP Sciences. https://doi.org/10.1051/shsconf/202315608004.
78. Mhlanga, D., & Ndhlovu, E. (2023). The fourth industrial revolution in Africa: An introduction. In *The Fourth Industrial Revolution in Africa: Exploring the Development Implications of Smart Technologies in Africa* (pp. 1-12). Cham: Springer Nature Switzerland.
79. Mohalik, R. K., Mohapatra, P. P., Mardaraj, P., Sahoo, S., Bhilala, A. K., Kar, N. B., & Dutta, S. K. (2020). First record of Boiga gokool (Gray, 1835)(Reptilia: Squamata: Colubridae) from Northern Odisha with notes on morphology and natural history. *Records of the Zoological Survey of India*, 189-192. https://doi.org/10.26515/rzsi/v120/i2/2020/147654.
80. Moloi, T. J., & Matabane, M. E. (2020). Reimagining the sustainable and social justice mathematics classrooms in the fourth industrial revolution. *International Journal of Learning, Teaching and Educational Research*, *19*(12), 281-294. https://doi.org/10.26803/ijlter.19.12.15.
81. Mphahlele, R., Seeletso, M., Muleya, G., & Simui, F. (2021). The influence of Covid-19 on students' learning: Access and participation in higher education in Southern Africa. *Journal of Learning for Development*, *8*(3), 501-515. https://doi.org/10.56059/jl4d.v8i3.515.
82. Mpungose, C. B. (2020). Student teachers' knowledge in the era of the Fourth Industrial Revolution. *Education and Information Technologies*, *25*(6), 5149-5165. https://doi.org/10.1007/s10639-020-10212-5.
83. Mulenga, E. M., María, J., & Prieto, M. (2018). Teachers Skills, Beliefs and Attitudes towards ICT Integration in the Teaching and Learning of Mathematics. A Local Study in Kabwe District in Zambia. *Journal of Global Research in Education and Social Science*, *11*(4), 176-189.
84. Naidoo, J., & Reddy, S. (2023). Embedding sustainable mathematics higher education in the fourth industrial revolution era post-COVID-19: Exploring technology-based teaching methods. *Sustainability*, *15*(12), 9692. https://doi.org/10.3390/su15129692.
85. Naidoo, J. (2022). Technology-based pedagogy for mathematics education in South Africa: Sustainable development of Mathematics Education post Covid-19. *Sustainability*, *14*(17), 10735. https://doi.org/10.3390/su141710735.
86. Nedungadi, P. P., Menon, R., Gutjahr, G., Erickson, L., & Raman, R. (2018). Towards an inclusive digital literacy framework for digital India. *Education+ Training*, *60*(6), 516-528. https://doi.org/10.1108/ET-03-2018-0061.

87. Ng'ambi, D. (2018). *Transforming teaching through the transformative integration of emerging technologies in the ePlay Maker Space: a critical, socio-cultural design-based study* (Doctoral dissertation, University of Cape Town).
88. Ngoatle, C., Mothiba, T. M., & Ngoepe, M. A. (2022). Navigating through the COVID-19 pandemic period in implementing quality teaching and learning for higher education programmes: a document analysis study. *International Journal of Environmental Research and Public Health*, *19*(17), 11146. https://doi.org/10.3390/ijerph191711146.
89. Asamani, J. A., Christmals, C. D., Nyoni, C. N., Nabyonga-Orem, J., Nyoni, J., Okoroafor, S. C., & Ahmat, A. (2022). Exploring the availability of specialist health workforce education in East and Southern Africa: a document analysis. *BMJ Global Health*, *7*(Suppl 1), e009555. https://doi.org/10.1136/bmjgh-2021-008418.
90. Olawumi, K. B., & Mavuso, M. P. (2023). Integration of environmental ethics education in the classroom: A review of literature. *International Journal of Environmental Sustainability and Social Science*, *4*(4), 1239-1252.
91. Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45-77. https://doi.org/10.2753/mis0742-1222240302.
92. Pettersson, F. (2021). Understanding digitalisation and educational change in school by means of activity theory and the levels of learning concept. *Education and Information Technologies*, *26*(1), 187-204. https://doi.org/10.1007/s10639-020-10239-8.
93. Pettinato, M. (2005). Predicting, understanding and changing: Three research paradigms regarding alcohol use among lesbians. *Journal of Lesbian Studies*, *9*(3), 91-101. https://doi.org/10.1300/j155v09n03_09.
94. Raaff, E., Rothwell, N., & Wynne, A. (2022, March). Aligning South African data and cloud policy with the POPI Act. In *International Conference on Cyber Warfare and Security* (Vol. 17, No. 1, pp. 279-287). Academic Conferences International Limited.
95. Raffaghelli, J. E. (2022). Educators' data literacy: Understanding the bigger picture. In *Learning to live with datafication* (pp. 80-99). Routledge.
96. Ramonyai, I. P., Marumo, M. L., Skhephe, M., & Matashu, M. (2022). Challenges of transformation in higher education curriculum development in South Africa during decolonisation. *Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: e-Saintika*, *6*(3), 157-172. https://doi.org/10.36312/esaintika.v6i3.703.
97. Rashid, S., & Yadav, S. S. (2020). Impact of COVID-19 pandemic on higher education and research. *Indian Journal of Human Development*, *14*(2), 340-343. https://doi.org/10.1177/0973703020946700.
98. Rassool, M. R., & Dissanayake, D. R. (2019). Digital transformation for small and medium enterprises (SMEs): with a special focus on the Sri Lanka context as an emerging economy. *International Journal of Business and Management Review*, *7*(4), 59-76.
99. Razak, F., Shin, S., Naylor, C. D., & Slutsky, A. S. (2022). Canada's response to the initial 2 years of the COVID-19 pandemic: a comparison with peer countries. *Cmaj*, *194*(25), E870-E877. https://doi.org/10.1503/cmaj.220316.
100. Reiter-Palmon, R., Forthmann, B., & Barbot, B. (2019). Scoring divergent thinking tests: A review and systematic framework. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 144. https://psycnet.apa.org/doi/10.1037/aca0000227.
101. Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2010). The selection of creative ideas after individual idea generation: Choosing between creativity and impact. *British journal of psychology*, *101*(1), 47-68. https://doi.org/10.1348/000712609X414204.
102. Rodríguez Aboytes, J. G., & Barth, M. (2020). Transformative learning in the field of sustainability: a systematic literature review (1999-2019). *International Journal of Sustainability in Higher Education*, *21*(5), 993-1013. https://doi.org/10.1108/IJSHE-05-2019-0168.
103. Rolls, K. D., Hansen, M. M., Jackson, D., & Elliott, D. (2020). Intensive care nurses on social media: An exploration of knowledge exchange on an intensive care virtual community of practice. *Journal of Clinical Nursing*, *29*(7-8), 1381-1397. https://doi.org/10.1111/jocn.15143.
104. Rosak-Szyrocka, J., Żywiołek, J., Zaborski, A., Chowdhury, S., & Hu, Y. C. (2022). Digitalisation of higher education around the Globe during covid-19. *Ieee Access*, *10*, 59782-59791. https://doi.org/10.1109/ACCESS.2022.3178711.
105. Rott, B., & Marouane, C. (2017). Digitalisation in schools–organisation, collaboration and communication. In *Digital Marketplaces Unleashed* (pp. 113-124). Berlin, Heidelberg: Springer Berlin Heidelberg.
106. Ruesch Schweizer, C., Di Giulio, A., & Burkhardt-Holm, P. (2019). Scientific support for redesigning a higher-education curriculum on sustainability. *Sustainability*, *11*(21), 6035. https://doi.org/10.3390/su11216035.
107. Selelo, M. E., & Manamela, M. G. (2022). Coining Online Teaching and Learning in Higher Education: Reference to COVID-19 Pandemic in South Africa. *International Journal of Social Sciences & Educational Studies*, *9*(2), 53-62. https://doi.org/10.23918/ijsses.v9i2p53.
108. Shulga, M. (2023). What does digital learning teach? *International Journal of Interactive Mobile Technologies*, *17*(9).

109. Singh, P. S. J., Oke, A. E., Kineber, A. F., Olanrewaju, O. I., Omole, O., Samsurijan, M. S., & Ramli, R. A. (2023). A mathematical analysis of 4IR innovation barriers in developmental social work—a structural equation modelling approach. *Mathematics*, *11*(4), 1003. https://doi.org/10.3390/math11041003.
110. Šlander, S., & Wostner, P. (2019). 5. Transformation and transition to industry 4.0: The Slovenian smart transformational approach. *Regional Studies Policy Impact Books*, *1*(2), 55-66. https://doi.org/10.1080/2578711X.2019.1621101.
111. Stringer, M. (2017). *The 2015 model principal supervisor professional standards: Transforming the role of principal supervisors* (Doctoral dissertation, Brandman University). https://doi.org/10.1016/S0140-6736(17)31666–5.
112. Suh, J., Yeo, S., & Lee, Y. (2024). Advancing teaching and learning of mathematics through transformative technology. *Research in Mathematical Education*, *27*(3), 253-265. https://doi.org/10.7468/jksmed.2024.27.3.253.
113. Taner, A., Akyıldız, S., Gülay, A., & Özdemir, C. (2021). Investigating education faculty students' views about asynchronous distance education practices during the COVID-19 isolation period. https://hdl.handle.net/20.500.12445/2933.
114. Tatira, B., & Kariyana, I. (2022). Defining formative electronic assessment in undergraduate mathematics: A reflective approach. *International Journal of Learning, Teaching and Educational Research*, *21*(7), 24-39. *https://doi.org/10.26803/ijlter.21.7.2*.
115. Timmis, S., & Muhuro, P. (2019). De-coding or de-colonising the technocratic university? Rural students' digital transitions to South African higher education. *Learning, Media and Technology*, *44*(3), 252-266. https://doi.org/10.1080/17439884.2019.1623250.
116. Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., ... & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and information technologies*, *28*(6), 6695-6726. https://doi.org/10.1007/s10639-022-11431-8.
117. Toader, T., Safta, M., Titirișcă, C., & Firtescu, B. (2021). Effects of digitalisation on higher education in a sustainable development framework—Online learning challenges during the COVID-19 pandemic. *Sustainability*, *13*(11), 6444. https://doi.org/10.3390/ su13116444.
118. Tokovska, M., Zaťková, T. Š., & Jamborová, Ľ. (2022). Digital competencies development in higher education institutions: A mixed methods research study. *Emerging Science Journal*, *6*(Special Issue), 150-165. http://dx.doi.org/10.28991/ESJ-2022-SIED-011.
119. Urhahne, D. (2018). Primary education and secondary education. *Educational Psychology*, *38*(7), 857-858. https://doi.org/10.1080/01443410.2018.1490241.
120. Van Rensburg, A., Theron, L., & Rothmann, S. (2015). A review of quantitative studies of South African youth resilience: Some gaps. *South African Journal of Science*, *111*(7-8), 1-9. http://dx.doi.org/10.17159/SAJS.2015/20140164.
121. Villarreal, M. E., Villa-Ochoa, J. A., & Galleguillos, J. (2023). Experiences of preservice mathematics teachers during their education in times of pandemic. *ZDM–Mathematics Education*, *55*(1), 235-248. https://doi.org/10.1007/s11858-022-01461-4.
122. Watermeyer, R., Crick, T., Knight, C., & Goodall, J. (2021). COVID-19 and digital disruption in UK universities: Afflictions and affordances of emergency online migration. *Higher education*, *81*, 623-641. https://doi.org/10.1007/s10734-020-00561-y.
123. West-Olatunji, C., Yang, M. J., Wolfgang, J., Henesy, R., & Yoon, E. (2017). Highlighting the challenges when conducting Cross-National studies: Use of transcultural theory. *Journal of Counselling & Development*, *95*(4), 457-464. https://doi.org/10.1002/jcad.12160.
124. Wiesböck, F., & Hess, T. (2018). *Understanding the capabilities for digital innovations from a digital technology perspective* (No. 1/2018). Arbeitsbericht. http://hdl.handle.net/10419/195925.
125. Woldegiorgis, E. T. (2022). Mitigating the digital divide in the South African higher education system in the face of the Covid-19 pandemic. *Perspectives in Education*, *40*(3), 197-211. https://hdl.handle.net/10520/ejc-persed_v40_n3_a13.
126. Xiang, Y. T., Yang, Y., Li, W., Zhang, L., Zhang, Q., Cheung, T., & Ng, C. H. (2020). Timely mental health care for the 2019 novel coronavirus outbreak is urgently needed. *The Lancet Psychiatry*, *7*(3), 228–229. https://doi.org/10.1016/S2215-0366(20)30046–8.
127. Yadav, S. K., Banerjee, A., Jhariya, M. K., Meena, R. S., Raj, A., Khan, N., ... & Sheoran, S. (2022). Environmental education for sustainable development. In *Natural resources conservation and advances for sustainability* (pp. 415-431). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00010-7.