Chapter 13
Digital Pedagogy for Mathematics and Technology Education: Exploring the Initiatives at One South African Teacher Education Institution

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Abstract In the Fourth Industrial Revolution era, globally, the use of digital pedagogy is progressing swiftly. This chapter discusses the findings of a qualitative study that explored mathematics and technology education students' perceptions and experiences of digital pedagogy in a developing country. The chapter focuses on one teacher education institution's initiatives to empower mathematics and technology education students to prepare them for teaching and learning in the digital age. The study was framed by connectivism, a network learning theory guided by the view that learning is a lifelong process that continuously acquires new information. For this study, postgraduate mathematics and technology education students who are also practising school teachers were invited to interactive online workshops and interviews focusing on teaching and learning using digital tools. Apart from showcasing the effects of the digital age on the teaching and learning process, this study's findings indicated the challenges of using digital pedagogy in a developing country. The advantages of virtual collaboration inspired by digital pedagogy are also discussed in this chapter. These findings have relevance globally and nationally when considering the perceptions, experiences, and implications of digital pedagogy in a developing country.

Keywords Connectivism · Digital pedagogy · Online learning · Mathematics · Technology · Students

13.1 Introduction

The digital world has entered education environments, with technology progressively being used to deliver education innovatively. Technology is increasingly used by society for various activities daily (Qurat-ul et al. 2019). Also, in the Fourth Industrial Revolution (4IR) era, there are mixed debates on how existing education

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J. Olivier et al. (eds.), *Perspectives on Teacher Education in the Digital Age*,
Future Education and Learning Spaces,
https://doi.org/10.1007/978-981-19-4226-6_13

environments should be transformed to support and incorporate digital pedagogy. Moreover, digital pedagogy developments have provided lecturers access to various digital tools and interactive digital platforms to change their 4IR education environment. Globally, institutions are introducing remote and online learning within their curricula, and digital pedagogy is essential to facilitate remote and online learning. In mathematics and technology education contexts, coupled with embracing online learning, are issues of what it means to incorporate digital pedagogy in a developing country.

In this study, digital pedagogy provided students and lecturers with various digital tools and platforms to discuss knowledge, content, perspectives, solutions to problems, assessments, skills and attitudes that aimed to encourage and guide online teaching and learning via the Internet.[1] Also, in this study, digital platforms and digital tools were aided by digital devices, for example, computers, document cameras and mobile devices that support digital pedagogy through video, audio, images and text (Peachey 2017). Digital tools in this study included, for example, websites, software programmes, PowerPoint presentations and online resources. Thus, digital pedagogy endorses digital platforms to effectively integrate digital tools and devices during teaching and learning (Buzzard et al. 2011). Consequently, digital platforms assist lecturers in using digital resources and tools to upload learning materials online. For example, the digital platforms Learn 2021,[2] Zoom[3] and Microsoft Teams[4] are combined software solutions that support online teaching and learning.

This study sought to respond to the main research question: What are postgraduate students' perceptions and experiences of initiatives used at their university to empower and prepare them for teaching and learning in the digital age. Moreover, this study was conducted during the COVID-19 pandemic era. The COVID-19 pandemic has transformed life, resulting in lockdowns globally. Globally, in the 4IR era, and contemplating the novel COVID-19 pandemic conditions, higher education institutions (HEIs) favour digital tools, digital devices and digital platforms to support digital pedagogy. Digital pedagogy, an approach for using digital platforms to teach and learn, is therefore seen as a means of avoiding the spread of the transmittable COVID-19 virus (Murgatrotd 2020).

[1] The Internet is a global system of connected computer networks that comprise government, public, business, private, academic and business systems linked by wireless, electronic and optical networking technologies.

[2] The Learning Management System (LMS) that is being used at the participating university is Learn 2021. This LMS is an open-source e-learning/online/digital platform.

[3] Zoom is a software application (app). This app allows one to network virtually with colleagues, family, friends and students when communication through face-to-face means is impossible. Zoom is used as an official digital platform for meetings, lectures, tutorials, consultations and practical sessions at the participating university.

[4] Microsoft Teams is an online platform developed by Microsoft. This digital platform is used by the participating university for chats, tutorials, sharing documents, meetings, lectures, videoconferencing and communication for students and lecturers.

13.2 The Fourth Industrial Revolution

In the Fourth Industrial Revolution (4IR) era, digital tools, digital devices and digital platforms transform the way we go about our daily lives. Moreover, the 4IR encompasses diverse approaches to integrating technology within society and the human body (Schwab 2016). In higher education environments, lecturers and students may be at different readiness levels for success in the 4IR; they may be digital immigrants or digital natives. Digital immigrants may obtain information on how to use digital tools. Rather than working online, they may initially examine their printed notes before going to the Internet for assistance (Helsper and Enyon 2009). In contrast, digital natives are acquainted with digital tools, devices and platforms, for example, the Internet, computers, smartphones and other digital tools, devices or platforms (Helsper and Enyon 2009). Digital natives would most probably thrive when using digital tools, devices and platforms when learning. However, digital immigrants may need additional support when using digital tools, devices and platforms. Thus, lecturers need to be aware of their students' abilities concerning their familiarity with digital tools, devices and platforms. This awareness would assist the lecturer when preparing and presenting the philosophies of the 4IR within the higher education environment.

Also, educational institutions need to change to adequately prepare their students for success in these situations (Butler-Adam 2018), and the 4IR influences the role of higher education in successfully preparing students for the digitally advanced society. To be successful, lecturers should take advantage of 4IR prospects. We need to change our pedagogy to include the effective use of digital tools, devices and platforms. Moreover, there has been criticism of the effect of the 4IR on developing and underdeveloped countries. Some countries do not have access to digital devices, stable Internet services, effective digital platforms, or adequate infrastructure to ensure that all members of society can access the essential digital devices to equally participate within a digitally progressive community (Zervoudi 2020). Apart from access to necessary digital tools, devices and platforms, to be successful in the 4IR, a vital requirement is training in the effective use of technology (Oprea 2014; Zervoudi 2020). Students and lecturers need to be adequately prepared to use technology within education environments, and they need to have the necessary exposure to digital pedagogy. However, in most underdeveloped and developing countries, for example, South Africa, preparing students and lecturers for digital pedagogy has only just commenced, and we now find ourselves amid the global COVID-19 pandemic.

13.3 Digital Pedagogy in Developing Countries

Its economic contribution often defines a country, and a developing country is a country with a "lower gross domestic product (GDP) per person" (Kuepper 2021, p. 1–3). The use of digital pedagogy has consequences for students in HEIs who live in a developing country, for example, South Africa. This is particularly valid for students living in contexts that are not conducive to online learning and teaching. For example, using a generic digital teaching and learning approach at HEIs can affect learning outcomes and the level of student performance (Sánchez and Singh 2018). In addition, a student's social background may influence achievement (Panthi 2016) due to the unequal educational opportunities available to students at HEIs (Ndimande 2016). In most South African HEIs, students are from rural contexts. They have limited access to essential services, such as housing, sanitation, internet connectivity and electrification (The World Bank 2018). In addition, all South African students do not have access to digital tools, digital devices, the Internet, data and other resources required to participate equally on digital platforms. Consequently, higher education students who live in rural contexts are limited from participating equally in higher education environments that favour digital pedagogy.

Thus, one of the significant concerns in higher education is ensuring equal access for all students, especially in developing countries (Gegel et al. 2015). At the same time, research has been conducted on using technology in mathematics higher education (Naidoo 2015; Schuck 2016). However, not much research has been conducted focusing on the implications of digital pedagogy for mathematics and technology higher education students living in unequal social contexts. The introduction of new technologies has changed pedagogy for HEIs globally. The physical presence of students is not necessary; however, this has implications for students from lower socio-economic backgrounds (Kromydas 2017). Students in developing countries may not participate actively and equally in online/digital higher education environments, resulting in unequal outcomes (Sánchez and Singh 2018). This is of particular concern, since mathematics and technology teacher education in the 4IR era requires that lecturers are prepared to include digital tools, devices and resources effectively within their contexts (Adom and Aravind 2019; Naidoo and Singh-Pillay 2020).

13.4 Digital Pedagogy for Mathematics and Technology Education

To prepare teachers for the twenty-first century, they must use digital pedagogy in their teaching (Pongsakdi et al. 2021). The use of technology by society has changed the way we network, think and conduct our day-day activities (De Wet et al. 2016). Digital tools, devices, platforms and resources advance novel approaches for thinking, collaborating and communicating (Klopfer et al. 2006). Pope and Mayorga

(2019) emphasise that many online platforms guide students' learning and achievement through education-based teaching and learning applications. The advantages of using digital tools, devices and platforms in mathematics, science and technology education have been reinforced by researchers (Cheung and Slavin 2013; Guzey and Roehrig 2009; Persson 2011). Also, digital tools, devices and resources can provide different problem-solving methods (Yang and Kwok 2017) and promote student collaboration in mathematics and technology educational environments (Naidoo and Singh-Pillay 2020).

In the 4IR, globally, education institutions are inclined to use digital tools for teaching and learning. So, too, in the study under focus, digital tools, devices, platforms and resources were used to teach and learn mathematics and technology education within a higher education context. Consequently, if digital pedagogy is going to be embraced, lecturers' knowledge of using digital pedagogy is essential to guarantee that digital tools, devices and platforms are used successfully (Qing 2003). Therefore, the lecturer must select suitable digital tools and resources to support students' learning when using digital tools, devices and platforms. Hence, designing digitally integrated lectures needs to be in harmony with the digital tools, devices and resources to provide maximum support for students' understanding (Drijvers 2013). Moreover, research (Adom and Aravind 2019; Cheung and Slavin 2013; Guzey and Roehrig 2009) has shown that using digital pedagogy for learning has advanced students' performance in mathematics, science, and technology education.

Research has been conducted on digital pedagogy, for example, dynamic software programmes in mathematics (Segal et al. 2021). Research (Dogruer and Akyuz 2020; Yeung and Ng 2021; Zhang 2021) has shown that using dynamic geometry environments enhances students' reasoning and conceptual understanding of the area and volume of three-dimensional (3D) shapes. Thus, the use of geometry software programmes was necessary for the study under focus. The mathematics workshop activities focused on using digital tools and a geometry software programme (Geometer's Sketchpad) to teach and learn the area and volume of 3D shapes.

For the technology education workshop activities, it was essential to raise awareness about the use of indigenous technologies for extending the lifespan of materials and the recycling of plastics. Globally, plastic waste has become a considerable challenge and endangers the environment (Awoyera and Adesina 2020). The recycling of plastics reduces the release of carbon dioxide into the air, which impacts global warming; in addition, recycling diminishes the use of oil and reduces the amount of waste produced (Hopewell et al. 2009). Moreover, it is important to consider ICT when teaching and learning about food preservation and extending the lifespan of materials. Using indigenous and new technologies to teach about the processes and skills involved in food preservation can enhance food security, ensure safe and sustainable food products, and reduce global warming (Raheem et al. 2019).

Although technology contributes to advancements in society, many students are still not competent technology users (Bennett et al. 2008) or do not have the digital devices required to effectively participate in a digital environment. South Africa is a developing country and, as such, students' access to digital devices is diverse. Challenges persist as students continually learn new skills in a digitally advanced

society (Ng'ambi et al. 2016). Educational environments need to be improved to prepare students to succeed in these environments (Butler-Adam 2018; Wahyuni 2018).

13.5 Exploring the Theory of Connectivism

The development of the theory of connectivism has been encouraged by advances in digital pedagogy and technology. Within the ambits of connectivism, students engage with digital pedagogies and interact on digital platforms to reflect on, share and improve their current knowledge and understanding.

Connectivism is a theory of learning proposed by George Siemens and is pertinent in our current digital era (Downes 2019). Siemens (2005) suggested that connectivism as a theory of learning is strengthened by existing digital tools and is founded on the view that the ever-present ICT impacts students' lives, learning and communication. Similarly, technology is necessary to develop digital pedagogy (Yang and Kwok 2017). Technology has transformed pedagogy such that digital pedagogy can develop successful teaching and learning by promoting online collaborations among students and lecturers (Vululleh 2018). While digital tools, devices and resources can support teaching and learning success, within the ambits of connectivism, digital devices and resources need to be readily accessible to all students, since accessibility has important consequences for student achievement and collaboration (Gilbert 2015).

Siemens (2005) maintained that connectivism could be regarded as a restructured form of constructivism appropriate for the technological era. Connectivism is a network system of information that emphasises using digital tools and resources to improve and extend online communication (Downes 2019). Integrating digital tools within education environments has been beneficial, as they have contributed to inspiring and developing higher-order thinking skills among students (Murphy 2016). Also, the valuable impact of integrating digital tools for teaching and learning can provide students with varied methods to complete their tasks independently (Ahmad 2015).

Connectivism supports students as they collaborate, communicate knowledge, solve and complete tasks (Downes 2019). Connecting students online with digital tools and resources does not essentially occur in a particular education environment; this is ubiquitous due to access to the Internet (Bell 2011). Thus, connectivism offers the lecturer a way of demonstrating aspects of teaching and learning that may not be directly observed or experienced (Duke et al. 2013). Connectivism suggests that knowledge, understanding and information advance in a system due to the collaborations within the group (Downes 2019). Thus, collaboration is reinforced within the ambits of connectivism, and opportunities for individual student learning are supported (Kizito 2016).

In this study, digital pedagogy enhanced the participants' understanding of using digital tools when teaching mathematics and technology education. The notions of connectivism were evident in this study as participants interacted via the digital

platforms to complete each workshop task. Thus, the tasks were completed after participants had engaged via digital platforms (Zoom, Microsoft Teams, Learn 2021, and WhatsApp) with the researchers and other students. In this study, the theory of connectivism was also helpful in illustrating how the participants adapted to using digital pedagogy. It was apparent that the participants made connections with current and new knowledge. Subsequently, after actively participating in the interactive digital-based workshops, the participants were invited to semi-structured virtual individual interviews. The interviews aimed to identify the participants' perceptions of using digital pedagogy for teaching and learning mathematics and technology education within the ambits of connectivism. The connections between current and new knowledge made by the participants were discussed further during the interviews.

13.6 Research Methodology

13.6.1 General Background

This qualitative, interpretive study explored digital pedagogy for mathematics and technology education and the initiatives used at one teacher education institution during the 2020 academic year. This institution is located in KwaZulu-Natal, South Africa. Gatekeeper approval, access and ethical clearance were obtained from the participating institution's research office. Participants were given an informed consent letter that outlined the purpose and various phases/stages of the study. Data were generated through interactive online workshops and online interviews via digital platforms. The participants' right to withdraw from the research should they wish to and request for permission to record the interactive online workshops and individual online interviews were also stated in the consent form. Moreover, the confidentiality and anonymity of all participants were guaranteed by using pseudonyms instead of the participants' names. Pseudonyms were created in the order the participant was interviewed. For example, Participant 2 refers to the second interviewee, and Participant 15 refers to the fifteenth interviewee.

13.6.2 Sampling

The study population comprised of Bachelor of Education Honours (B.Ed. Hons) in mathematics and technology education students registered at the participating university. All students enrolled for an honours degree in mathematics and technology education at the participating university were invited to participate. A total of 64 B.Ed. Hons students were invited to participate in the study. Of the 64 B.Ed. Hons students who were invited to participate, 43 responded positively. Participation in the data generation phase for this study was voluntary (Šorgo and Špernjak 2020).

Participants who did not agree or volunteer to participate in this study were excluded from the pilot and main study selection. All study participants were also mathematics or technology school teachers, the cases under investigation.

13.6.3 Pilot Study

A sample of 10 participants was selected at random for the pilot study. The pilot study was conducted to ensure the reliability and validity of the research instruments and the research process. As a result, the research instruments were modified. For example, the interview schedule was revised so that the questions were clearly defined, well-structured and easy to understand. In addition, probing questions were rephrased to eliminate vagueness. The language used during the workshops and the interviews was specific and straightforward to increase dependability. The remaining 33 participants participated in the main study. Data were generated by conducting two interactive online workshops and individual semi-structured online interviews.

13.6.4 Interactive Online Workshops

For the main study, two workshops were conducted. Thirty-three participants participated in these workshops. The researchers facilitated these workshops held on two Saturdays during the second semester (July–December) of the 2020 academic year. One workshop was conducted using the Microsoft Teams platform, and the second workshop was conducted using the Zoom platform. The workshops lasted approximately six hours per Saturday, with two breaks between the online workshop activities (one 30 min tea break, and a one-hour lunch break). The workshops were focused on exploring digital pedagogy for mathematics and technology education. Activities focused on exploring the initiatives of the one institution under focus. These initiatives empowered mathematics and technology education students to prepare them for teaching and learning in the digital age. The workshops' content included teaching and learning surface area and volume of 3D objects, as well as teaching and learning processes involving indigenous technologies. The mathematics workshop activities focused on enhancing students' conceptual understanding of calculating the volume and area of 3D shapes. Students were given the opportunity to manipulate and drag shapes on their screens during the workshops while using the Geometer's Sketchpad programme. Consequently, students could see the effects of these hands-on manipulations on the final solution for the area and volume of the 3D shapes under focus.

The learning activities for mathematics and technology education were not linked, since the mathematics activities were conducted with participants who taught mathematics at schools. The technology education activities were undertaken only with participants who taught technology education at schools. The learning outcomes for

the mathematics activities focused on the participants' ability to use formulae for measuring area, surface area, perimeter, the volume of 3D objects, and select and convert between suitable units of measurement. The learning outcomes for the technology activities focused on the participants' ability to apply technological processes and skills to extend the lifespan of materials using indigenous technologies. Additionally, recycling plastics to provide the raw material for manufacturing new plastic products was also discussed during the interactive online workshops. This topic was specifically selected due to the global concern on the use of fossil fuels in the making of plastics and the effects of this process on global warming (Awoyera and Adesina 2020; Gervet 2007). Fossil fuels are a limited resource (Cui et al. 2010). Discussing the recycling of plastics in the workshops provided critical awareness of the need to conserve fossil fuels and thereby reducing global warming.

Participants were provided with video clips and presentations at each workshop, focusing on teaching notes, examples of lesson plans, demonstrations, concrete manipulatives, models of assessments and demonstrations of how digital pedagogy could be embedded effectively within mathematics and technology education classrooms. Next, participants were invited to participate in online individual semi-structured interviews at the end of Semester 2 (December) of the 2020 academic year. This meant that all participants would have the chance to reflect on what they had learnt from the workshops. Their learnings would possibly advance their knowledge and use of digital pedagogy in their future teaching practice.

13.6.5 Online Interviews

Participants were interviewed via digital platforms. These interviews centred on participants' perceptions and experiences of digital pedagogy. Although 33 BEd Hons mathematics and technology education students participated in the two interactive online workshops for the main study, only 22 participants were available for individual online interviews due to personal reasons. The participants were interviewed using the Zoom, WhatsApp,[5] Skype, and Microsoft Teams digital platforms. Participants chose the digital platform they were most comfortable using, ensuring that each participant felt at ease during the interviews. Participants also selected the day and time of the interviews; this ensured that they were available for the online interview. The reason for choosing semi-structured interviews was that each interview item's responses could be probed to acquire accuracy. Participants could also openly ask for interview questions to be explained further. This type of interview also allowed the researchers to clarify replies. The interviews were used to clarify each participant's perception and experiences of digital pedagogy for mathematics and technology education.

[5] WhatsApp is a free messenger application (app) that uses the Internet to receive and send calls and messages. WhatsApp was used as a digital platform unofficially at the university under study.

The online interviews focused on the following key questions:

- What were the participant's perceptions and experiences of digital pedagogy for mathematics and technology education?
- What were the strengths or challenges of using digital pedagogy within mathematics and technology education classrooms?
- Were the two workshops beneficial to the participants, as they integrated digital pedagogy within their lessons at school?
- Did the initiatives employed at the university empower and prepare the participants for teaching and learning in the digital age within the ambits of connectivism?

These interviews were recorded and then transcribed. Transcripts were sent to each participant to ensure the accuracy of what was stated during the interview. Subsequently, all the data that were generated during the main study were analysed.

13.6.6 Data Analysis

Data analysis for this study entailed coding and categorising themes and was based on the conceptual framework of the research, i.e., the theory of connectivism. As a result of the data analysis process, codes for describing participants' replies to each interview question were developed. Data generated from the workshops and interviews were analysed qualitatively. After each interview transcription was completed, the interview data were scrutinised and segmented into essential codes. This type of coding revealed the participants' perceptions and experiences of using digital pedagogy for mathematics and technology education. These codes were carefully reviewed and summarised as themes. Thematic coding was used to create themes inductively. The identified themes provided a clear picture of the participants' perceptions and experiences of digital pedagogy for mathematics and technology education. Four main themes emerged from the qualitative content analysis of the interview transcripts. Participants' perceptions and experiences of digital pedagogy for mathematics and technology education were as follows: Digital pedagogy has strengths for teaching and learning; digital pedagogy can empower and motivate teachers; digital pedagogy inspires virtual collaboration among the connected online community; and digital pedagogy exposes challenges in a developing country.

13.7 Findings

While, in general, the participants appreciated the use of digital pedagogy for mathematics and technology education, they did indicate that, apart from strengths, there are also challenges when using digital pedagogy in a developing country. The participants' responses concerning the initiatives employed by the participating university are described next.

13.7.1 Digital Pedagogy Has Strengths for Teaching and Learning

The interview responses showed that the participants valued digital pedagogy for mathematics and technology education. The participants mentioned the strengths of using digital pedagogy for teaching and learning. The interview transcript excerpts that follow support this view.

> P3: …technology tools help as we view the different indigenous design processes…seeing these processes in the video makes learning about them easier…
>
> P4: …seeing and moving the diagrams using Sketchpad[6] made it easier to calculate the volume of the cone…using technology made a difference…
>
> P6: …Sketchpad helped to calculate dimensions and also helped us know what we were working with…we could see the diagrams and identify them quickly…
>
> P9: …we saw how to calculate and solve the volume and area it made it easier…we saw…step by step process as we viewed the screen…the hovercam[7] displayed each step and each key that was used on the calculator…we could follow and solve easily…
>
> P14: …we could identify each real-world shape that was displayed in the video…much better to see the video than just hear about it…the step by step solution process in the presentation was easy to follow…we could also rewind the video if we did not understand or if we missed something…
>
> P18: …hovercam displayed all the steps…real-time…could ask for clarification as we worked…the solution could be explained again in real-time with the hovercam…later we could view the recording to understand better when we were working on our own…

Various digital tools and online resources, such as videos, PowerPoint presentations, the hovercam, Geometer's Sketchpad, and visually enriched demonstrations, were integrated into the interactive workshops to succeed with digital pedagogy. This is aligned with the theory of connectivism. Technology is a crucial part of the teaching and learning process and offers opportunities to choose our teaching and learning strategies. As is evident from the preceding excerpts, these digital tools and resources strengthened the teaching and learning of mathematics and technology education in this study.

13.7.2 Digital Pedagogy Can Empower and Motivate Teachers

The participants indicated that using digital tools and resources increased their confidence levels, and they noted that using digital pedagogy would benefit their

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[6] The Geometer's Sketchpad programme is a software programme for teaching mathematics.

[7] The hovercam is a mobile document camera which links to one's computer so that one can teach in real time and display on one's computer as one teaches. One can use the hovercam to magnify images and manipulatives to make them easier to see. In addition, one can record lessons/lectures using the hovercam.

learners. The participants believed that using different websites, videos and software programmes would make their lessons more interesting and save time in the class. This created a sense of empowerment, and the participants felt motivated to teach their future lessons in this manner. The interview transcript excerpts that follow exhibit these notions.

> P1: …using different technology tools makes me more confident… I can always use other websites to ensure I am on the right track…
>
> P4: …feel better that I can use videos and software to help me as I teach…some 3D shapes… challenging to explain and draw…I can use the different websites to show examples with correct drawings…and videos of how to solve area and volume…
>
> P7: …more confident…know more now using the Internet and the different maths sites…feel better, and my learners will benefit more…
>
> P12: …using technology makes me want to teach differently…it is exciting to me…we can see how different cultures designed the different cultural objects…better to watch and learn using the video…takes less time than using the board to draw…I can teach more concepts using videos and presentations…
>
> P16: …I feel comfortable now using the Internet and the online resources…I want to show my learners more examples of different designs…I am eager to teach more now…
>
> P21: …we only used the textbook…my learners don't focus much…they do not talk much…now with the different tools and websites…so many examples…I know my learners will be excited…I am eager to teach…I have all these resources from all over the world to use…
>
> P22: …technology makes it easier to teach…teach more concepts in less time…any questions…by using the different websites and videos as we did in the workshop…more interesting lessons…step by step design with pictures…

The use of digital pedagogy during the workshops created a transformation in teaching, learning and assessing, which changed how the participants viewed their current teaching practice. Instead of using traditional paper-based assessments, the assessments were conducted online using the Learn 2021[8] digital platform. Students were required to complete their assessments electronically and submit their responses on the Learn 2021 platform. As was evident, within the domains of connectivism, digital tools and devices are an important part of teaching, learning and assessing and allow for the transformation in traditional teaching, learning and assessment processes. This study showed that digital pedagogy stimulated the participants' interests and promoted self-confidence in planning and teaching their future lessons. The participants were empowered and motivated by what they had learnt during the interactive workshops. Based on the preceding interview transcripts, it was evident that the participants now knew a wide range of digital tools and resources to use in their future teaching.

[8] The Learn 2021 platform is the digital Learning Management System (LMS) that is being used at the participating university.

13.7.3 Digital Pedagogy Inspires Virtual Collaboration Among the Connected Online Community

The participants indicated that using digital pedagogy increased virtual collaboration in the online community. Based on the findings of this study, digital pedagogy encouraged the participants to collaborate online. This online collaboration was supported by the use of digital platforms, for example, WhatsApp. This is supported by the following interview transcript excerpts.

> P2: …easy to get help online from my class…share resources… problem-solving ideas and tips online…quicker this way…
>
> P3: …we help each other online…discuss using WhatsApp…share our practice online…-more help this way…
>
> P8: …convenient to use WhatsApp…share our ideas and resources…more help online…all work together, and give ideas on how to solve problems…even share worksheets on WhatsApp…
>
> P13: …can always ask for help online…someone always responds…we can discuss our challenges with the group online…more efficient sharing online…
>
> P15: …class works well online…someone is always available to help…share the problems in a topic…class posts activities and worksheets that I can use…
>
> P20: …better way to work now…always get ideas from the class…have a problem we can discuss solutions quickly online…class is available to assist me online…

Participants were encouraged to discuss their challenges and share their ideas, problem-solving strategies, resources, and activities online to achieve virtual collaboration. As was evident, through the use of digital platforms, the participants collaborated extensively. The most common digital platform used for this virtual collaboration was WhatsApp. This is aligned with the theory of connectivism in that digital platforms, devices and resources are essential for encouraging a connected and collaborative teaching and learning process.

13.7.4 Digital Pedagogy Exposes Challenges in a Developing Country

From the responses in the online interview, it was apparent that some participants had reservations about the use of digital pedagogy in their contexts. These participants mentioned the challenges associated with unstable internet connections, the high cost of purchasing data, the numerous power cuts resulting from load shedding,[9] and not

[9] Load shedding is a planned interruption in electricity supply by the Department of Electricity in South Africa. Load shedding refers to the disturbance of electricity supply to avoid unnecessary overload when there is a high request for electricity. All consumers are informed in advance of load shedding times within their areas through the use of a comprehensive schedule. However, these timetables are not always adhered to.

having access to the necessary digital devices. The following excerpts support this view.

> P5: …sometimes it is difficult when internet connectivity is bad…I have the online resources and videos…difficult to load when the Internet is bad…

> P8: using WhatsApp on my phone is great…no internet then it is a problem…very unstable connections in my area…this is the downside of using technology…also I don't have all the gadgets…

> P10: I am all for using technology and the Internet when I teach…difficult for me…live and teach in a rural area… no good infrastructure for the Internet…connectivity is always breaking…also our electricity is always cutting off…especially with load shedding…not predictable…so it is hard for me to use the Internet and technology when I teach…also it is expensive to buy all these devices…

> P11: …I need to have plan A and plan B for my lessons…plan A I prepare using the textbook and the board, and plan B I prepare with videos and online resources…stressful when I want to use the Internet and then it is down in my area because the Internet is not good in rural areas or if there is no electricity because of load shedding…load shedding timetable is not always correct…

> P16: …enjoy using online videos and resources when I teach…problem when there is no internet…this often happens in my place…connections not dependable in my area…this wastes a lot of time when I am teaching…

> P17: …so much to do with technology for maths lessons…can't always use the online methods…internet connectivity is not stable in my rural area…I don't have many tools to use…

> P19: …I don't use much technology or online resources in my teaching…pointless since internet connectivity is very poor where I teach…can't always buy data to use in my lessons…expensive…some videos take lots of time to upload…lots of data is used…also I do not have all the devices…

> P22: …lessons…more interesting…using online websites and resources…problem with my internet connection…not very good where I teach…sometimes I can't load the website…can't access the Internet…not good…

The preceding transcript excerpts indicate that, despite the challenges the participants mentioned, they valued the use of digital pedagogy. Within the ambits of connectivism, digital platforms allow participants to collaborate and make informed choices about teaching and learning. However, unstable internet connections, numerous disconnections of electricity, the expenses incurred for purchasing data, and limited access to digital tools affected the participants' ability to use digital pedagogy within their educational environments. This is common in a developing country like South Africa. Thus, the relevant role players within the education sector need to collaborate to ensure that classrooms are equipped with the necessary resources and requirements to embrace digital pedagogy in the era of the 4IR.

13.8 Discussion and Conclusion

The aim of this study was to explore participants' perceptions and experiences of digital pedagogy at one university in KwaZulu-Natal, South Africa. Participants were invited to two interactive online workshops and were consequently interviewed using digital platforms. Four main themes emerged from the qualitative analysis of the interview transcripts, namely digital pedagogy has strengths for teaching and learning; digital pedagogy can empower and motivate teachers; digital pedagogy inspires virtual collaboration among the connected online community; and digital pedagogy exposes challenges in a developing country.

The participants valued the use of various digital tools, devices, platforms and resources and maintained that exposure to digital pedagogy allowed them to envisage a transformed pedagogy. Digital pedagogy in this study encouraged active online collaborations among students and lecturers, leading to successful teaching and learning (Vululleh 2018). These ideas are supported within the ambits of connectivism, as students collaborate and solve tasks online (Downes 2019). The participants viewed the initiatives at the participating university as empowering and motivational. They were exposed to different digital tools, devices, platforms and resources. These experiences encouraged participants to have the confidence to transform their perceptions of teaching their future lessons. Within the ambits of connectivism, opportunities for individual learning are supported (Kizito 2016), and existing knowledge and understanding progress due to the online collaborations within a virtual group (Downes 2019).

Furthermore, the participants indicated that the use of digital pedagogy encouraged active virtual collaboration. This result resonates with research (Downes 2019; Kizito 2016), whereby collaboration promotes learning and is reinforced within the ambits of connectivism. As was evident in this study, the participants were encouraged to virtually share their ideas, resources, challenges and problem-solving techniques. They were encouraged to communicate and collaborate online using various digital platforms at any time. Connecting students online with digital tools, devices and resources is ubiquitous due to access to the Internet (Bell 2011). As was evident in this study, the participants collaborated online and discussed mathematics and technology education problems using digital pedagogy. Participants constructed knowledge and meaning in their connected online group. Similarly, connectivism can be regarded as a restructured form of constructivism (Siemans 2005). This learning theory requires digital tools and resources to expand and extend online communication, collaboration and knowledge construction (Downes 2019).

The participants in this study mentioned the challenges of digital pedagogy in a developing country like South Africa. These challenges included unstable internet connections, the high expenses associated with using digital pedagogy, the lack of electricity due to load shedding, and limited access to the necessary digital devices. The findings of this study reveal that these challenges shaped the participants' experiences and perceptions of integrating digital pedagogy within their classrooms (Klopfer et al. 2006). Similarly, in connectivism, digital tools, devices, platforms

and resources can support teaching and learning success. However, digital tools, devices, platforms and resources must be easily accessible, since accessibility has significant consequences for achievement and collaboration (Gilbert 2015).

This study has provided interesting perceptions and experiences concerning the initiatives used at the participating university. The findings of this study showed that, within contemporary mathematics and technology education contexts, digital tools, devices and resources are important. If the notions of connectivism are embraced, teachers would seek to integrate digital pedagogy in their educational contexts to amplify the benefits to student learning. However, for the successful integration of digital pedagogy in the 4IR era, easy access to digital tools, devices, platforms and resources are essential. In the 4IR era, access to digital tools, devices, platforms and resources would benefit teachers in developing countries, for example, South Africa, and other developing countries globally.

More studies on a larger scale to explore mathematics and technology teachers' perceptions of using digital pedagogy are necessary. Opportunities for future studies could include qualitative studies conducted at different South African universities. Comparable studies could also be conducted at universities globally. Large-scale data may provide greater dependability and prospects for further qualitative analysis and clarification. Opportunities for national and global quantitative studies to explore teachers' perceptions of using digital pedagogy when teaching mathematics and technology education could also be explored. This would be useful for increasing the knowledge base in the field nationally and globally.

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