Disruptions in higher education:
Impact and implication

Volume 2

The 4IR and teacher education in South Africa

Contemporary discourses and empirical evidence

FELIX MARINGE & OTILIA CHIRAMBA (EDS.)

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The 4IR and teacher education in South Africa

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Editors
Felix Maringe
Otilia Chiramba

AOSIS

Peer review declaration

The publisher (AOSIS) endorses the South African 'National Scholarly Book Publishers Forum Best Practice for Peer Review of Scholarly Books'. The manuscript underwent an evaluation to compare the level of originality with other published works and was subjected to rigorous two-step peer review before publication, with the identities of the reviewers not revealed to the editor(s) or author(s). The reviewers were independent of the publisher, editor(s), and author(s).

The publisher shared feedback on the similarity report and the reviewers' inputs with the manuscript's editor(s) or author(s) to improve the manuscript. Where the reviewers recommended revision and improvements, the editor(s) or author(s) responded adequately to such recommendations. The reviewers commented positively on the scholarly merits of the manuscript and recommended that the book be published.

Research justification

The research presented in this scholarly book is all original, whether it is theoretical or empirical as it deals with a new phenomenon in the South African context and as it seeks answers to questions that have hitherto not been asked before. The 4IR has become an overarching framework within which education systems including teacher education are operating. Contingent upon the ideology of neo-liberalism, the 4IR seeks to transform societies in ways that respond to the relentless developments in technology, the Internet and digital capacities, which, by design and intent, are purposed at increasing both the productivity and the associated quality, while at the same time reducing human intervention in the same processes. In teacher education, how we teach and train student teachers will be substantially influenced by the imperatives of the 4IR. There are multiple unresolved questions as the 4IR takes centre stage. For example, what will it mean for teaching and learning in schools that have severe technological and digital deficits; for teachers and students who have minimal technological literacies; for delivering high-quality teaching and learning; for transforming both the content and pedagogies of teacher education and, above all, for delivering socially just educational experiences for all our learners, regardless of class, race and privilege. The discourse of the 4IR is contemporary and requires multiple perspectives to explore what it means in different contexts and settings, and the understandings it engenders in people, what it implies across a wide range of educational decision-making levels, and that its fundamental assumptions cohere with national and societal assumptions about equality, equity and social justice. Multiple methodological approaches were utilised in the interrogation of the idea of the 4IR in teacher education in South Africa, including theoretical, empirical, small-scale case studies amongst others. The data these approaches provide are equally valued based on the purposes for which they have been derived. Prior to publication, each chapter was subjected to a similarity analysis to determine any textual similarities. In all cases, authors were required to respond to the similarity reports to assure that the substantiation of argumentation is based on appropriate, sound and scholarly responsible recognition of relevant sources. As editor, I can therefore confidently declare that all the material covered in this book has not been plagiarised. This book is written for researchers in the broad fields of social sciences and humanities with a specific focus on those in the fields of education and teacher education in particular. Postgraduate researchers will also find the material in this book useful.

Felix Maringe, Department of Educational Leadership and Policy Studies, Faculty of Humanities, University of the Witwatersrand, Johannesburg, South Africa

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Abbreviations, figures and tables appearing in the text and notes

List of abbreviations

ADP	Advanced Digital Production
AI	Artificial Intelligence
CoI	Community of Inquiry
CPD	Continuing Professional Development
CTPD	Continuous Teacher Professional Development
DBE	Department of Basic Education
DoE	Department of Education
F2F	face-to-face
Gen Z	Generation Z (1997–2012)
HE	Higher Education
HEIs	Higher Education Institutions
IARU	International Alliance of Research Universities
ICT	Information Communication Technology
IoT	Internet of Things
LMSs	Learning Management Systems
MIM	Mobile Instant Messaging
MP	Mathematical Practice
MPH	Mathematical Pedagogical Habitus
NRF	National Research Foundation
NWU	North-West University
OBE	Outcomes-based Education
OHP	Overhead Projector
PD	Professional Development
PGCE	Postgraduate Certificate in Education
PH	Pedagogical Habitus
PhET	Physics Education Technology
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SDL	Self-directed Learning
SES	Socio-economic Status
SIoT	Social Internet of Things

SJM	Social Justice Mathematics
SMT	School Management Teams
SSMT	Secondary School Management Teams
SST	Social Shaping of Technology
TD	Teacher Development
TPACK	Technological, Pedagogical and Content Knowledge
TPD	Teacher Professional Development
TPI	Technological Profile Inventory
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
UNISA	University of South Africa
UWC	University of the Western Cape
VLE	Virtual Learning Environment
VR	Virtual Reality
ZPD	Zones of Proximal Development

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Chapter 1

The emerging discourse of the 4IR: Theoretical and conceptual overview in the context of teacher education in South Africa

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Abstract

From time to time, education has suffered a setback as a result of major disruptions. Some were epidemiological such as the current COVID-19 being experienced. Seismological events such as earthquakes shake the foundations of nations rendering schooling impractical in the ordinary sense. Other ideological factors include situations when a compelling ideological conviction

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grips the consciousness of a nation or nations causing ripples in the system and requiring a recalibration of the meanings and purposes, content and methods of education. In the global South, and especially in post-colonial nations such as South Africa, we face a triple cocktail of major disruptions, in the form of the Fourth Industrial Revolution (4IR), decolonisation and the COVID-19 pandemic. This confluence of major disruptions in Africa's higher education spaces at the same time can trigger major changes some of which could have undesirable consequences for both the institutions and the societies they serve.

This book, the second in the series, brings together empirical evidence in the teacher education contexts demonstrating the capacity, challenges, contradictions and conundrums faced in teacher training in South Africa as they respond, prepare for and adjust to the imperatives of the 4IR. The book brings together gilt-edged theoretical thinking and empirical evidence around the discourses of the 4IR and their application in teacher education contexts.

In this chapter, the focus is on a critical examination of the discourse of the 4IR, discussing its ontological and epistemological foundations and reflecting on how these intersect with contextual realities of teacher education in South Africa. The chapter is conceptualised as offering a broad-based foundation for reflecting the affordances and constraints of integrating the ideas of the 4IR in teacher education.

Introduction

The 4IR is an emerging discourse that represents projected developments in the key areas of technology and digital systems and how these are set to revolutionise all aspects of our lives, including patterns of human interactions, the transformation of careers and professions and the centring of knowledge and innovation as key stimuli for development. Schwab (2017) has noted that the 4IR has a range of new technologies that integrate the physical, digital and biological worlds, thus hugely impacting all disciplines, economies and industries and even challenging ideas about what it means to be human. The key technological developments at the heart of the 4IR include artificial intelligence (AI), robotics or automation, the Internet of Things (IoT), 3D printing, genetic engineering and quantum computing amongst others. While it is beyond the scope of this book to delve into details about each of these, we will devote some space, albeit limited, to describing these developments as they are envisaged to be at the heart of the disruptions set to affect all facets of life, economies and human relations. As the purpose of this book is to reflect the potential impact of the 4IR in teacher education, we provide a brief background of this aspect of human capital development in the South African context.

Teacher education is a vital dimension of human capital development in any country (Sayed 2002). It is through teacher education that countries train or educate teachers for the school systems, through which the nations' human capital is capacitated and skilled to become economically productive citizens. In South Africa, teacher education is in a state of transition, having been developed in the apartheid era for the domination of indigenous populations by minority white settler regimes. Prior to 1994, separate colleges were established for training teachers for a racially differentiated system of education. Two key developments occurred in teacher education following the end of apartheid in 1994. These included the establishment of a single ministry of education rather than separate ones based on race and the incorporation of colleges of education into universities where they became departments, schools or faculties of education aimed to rationalise teacher education (Sayed 2002). This was in line with the democratic ambitions of the new government which sought to establish a non-racist, non-segregated and equal society from the ashes of a highly polarised apartheid society. The schools had a similar history and structure, with the majority black learners attending very poorly resourced schools with collapsing infrastructure and poorly trained teachers while the minority white children went to lavishly resourced schools with excellent infrastructures and highly trained teachers (Hay & Monnapula-Mapesela 2009). However, despite the end of apartheid, the education system, just as the economic, financial systems, continues to reflect the binary worlds of apartheid (Villette 2016), one for the poor and another for the rich, which tend to trace the contours of race and privilege that persist even after almost 30 years from the attainment of democracy (Fleisch 2008; Spaull 2013). This reality has serious implications on how the 4IR is likely to impact the education sectors and teacher training, characterised by substantial differences in affluence and poverty and which serve diametrically different societies in the same country, an issue we shall return to later.

While technological and digital developments that are driving the 4IR are set to revolutionise all spheres of life, we do not know much about how the differentiated school systems in South Africa are ready to grapple with the imperatives of the 4IR and how these systems need to prepare themselves for adopting and adapting to the technological and digital revolutions. We also do not know enough about how school curricula are likely to be impacted by these changes, what new pedagogical and assessment forms will be required in the 4IR context.

This chapter thus critically examines the discourse of the 4IR, discussing its ontological and epistemological foundations and reflecting on how these intersect with contextual realities of teacher education in South Africa. The

chapter is conceptualised as offering a broad-based foundation for reflecting the affordances and constraints of integrating the ideas of the 4IR in teacher education. We begin with an expanded outline of the context of teacher education in South Africa.

Teacher education in South Africa

As noted earlier in the text, teacher education in South Africa, which emerged from the crippling and highly segregated system of apartheid, continues to be producing teachers for a highly divided society. On the GINI indexes, statistical measures of economic inequality in a population, South Africa is listed as one of the most economically divided societies in the world, in which almost 75% of the population live in poor rural and township environments characterised by weak socio-economic infrastructures, a largely agrarian economy that is poorly mechanised and with unreliable technological and Internet services (Piketty 2020). Some learners in these schools are recipients of social grants and free school meals pointing towards high levels of poverty and deprivation. Their learning is essentially teacher-driven and provided by professionals with arguably the lowest qualifications and who therefore are unable to deliver high-quality education (Sayed 2002). On the other hand, most of the schools in the formerly white-only urban centres have the best teachers, abundant resources and are technologically compliant with the requirements of the 4IR.

Teacher education in universities in South Africa is imparted in three different spaces. In some cases, it takes place in schools of education; in others, it is conducted in departments or divisions of education in more complex schools that host disciplines other than education; in other cases, teacher education exists as faculties of education. While the curricula for teacher education differs between providers, there tend to be three or four crucial and common elements across the universities. All teacher trainees undertake a four-year Bachelor of Education (BEd) programme that combines the study of specific subject disciplines up to about the third-year level of study in other non-teaching degrees. They then undertake a fourth year in which the education disciplines are integrated. The BEd degree is typically integrated, allowing students to study both content and methods concurrently. A smaller number of trainee teachers undertake the postgraduate certificate in education (PGCE) qualification, in which the students first complete a four-year undergraduate degree in subjects that can be taught in schools before embarking on one-year full-time education studies after which they are awarded the PGCE, a qualification considered to be an equivalent of the BEd degree. However, while they may be considered as equal on paper, this does not always translate to in the real world of work (Verbeek 2014).

All teacher training programmes include a period of off-campus training in schools for pre-service trainees. The length of school-based training is

determined by the Department of Basic Education (DBE), the key employer of all trained teachers who graduate from university teacher training programmes. At university, trainees study the content in teaching subjects at degree equivalent levels, pedagogy or teaching and learning methodologies, curriculum studies and educational foundation studies in philosophy, psychology, sociology and the management of teaching and learning.

Teacher training in South Africa has been described as evidencing five critical dimensions that we believe have relevance to the debates around the 4IR. These relate to: the Eurocentric nature of its epistemological basis; a growing sensitivity towards the need to decolonise; urban centricity; relatively poorly resourced compared to sister departments across the universities; admits students from the lower-end performers at the Matric level; relatively unmotivated students who tend to use teacher education as a stepping stone to other study opportunities in the universities and staff who contribute at the lower end of the intellectual ambition of the universities. We further try to demonstrate how these characteristics might present challenges and barriers to transformation in the context of the 4IR.

☐ Eurocentric nature of the teacher education curricula

The Eurocentric nature of South African university curricula is a widely acknowledged fact (Griffiths 2019). Heleta (2016) argues that the 'epistemologies and knowledge systems at most South African universities have not considerably changed' and 'they remain rooted in colonial, apartheid and western worldviews and epistemological traditions' Heleta (2016:1). The situation is no different in teacher education, where, apart from a few tweaks here and there, the training curricula closely mirror those that were used before 1994, both in terms of content and methodologies. On one hand, this provides a relatively easy route towards integrating a very strongly Eurocentric or South American centric idea of the 4IR into teacher education in South African universities. On the other, it could create a situation where teacher education providers provide a curriculum that has very little resemblance and relevance to the realities of schools that are technologically under-resourced, especially those located in rural areas and facing multiple deprivation (Maringe & Moletsane 2015).

☐ A decolonised teacher education

Following the 2015/16 #RhodesMustFall and #FeesMustFall student-led protests originating at University of Cape Town and University of the Witwatersrand, respectively, higher education in South Africa is currently in the tumble dryer, trying to spin its way out of the stranglehold of the western canon. While the students' voice on this matter is highly respected and acknowledged, there seems little inclination to embark on this journey at

the higher levels of the academy. Much of the foment towards decolonial higher education seems to be embedded in divisions, schools and faculties, which represent the peripheries of decision-making. Despite its importance, a senior management portfolio responsible for decolonisation across the university sector in South Africa still remains lacking. With its focus on issues of equality, equity, the development of African identities and the development of indigenous knowledge systems, we propose that the net impact of the decolonisation agenda is to tame the potential of the 4IR to drag the academy deeper into the abyss of coloniality especially because of its origins and close links with liberalism and post-modernity (Maringe & Chiramba 2021).

Teacher preparation in South Africa

Geo-spatially, many universities are located in the urban centres of South Africa. Most students prefer to pursue their off-campus teaching practice in urban schools and go to rural schools only when they are faced with little or no choice (Ndofirepi & Masinire 2020). This tends to reinforce their dislike for rurality and contribute to the perpetuation and entrenchment of rural school poverty in comparison to the flourishing wealth of urban schools. At one university, efforts have been made to encourage students to go and practice in rural schools and this has resulted in a growing but still insignificant interest in working in rural schools after graduation (Masinire 2020). The urban-centric nature of teacher education has the potential to create a suitable environment for the growth and integration of 4IR in teacher preparation. However, the darker side (Mignolo 2017) of this reality is that it tends to render teacher preparation irrelevant for some schools, especially those in the rural areas. It is one thing to learn about rurality and quite another to live it.

Resource poverty in teacher education departments

In many universities, teacher education departments tend to be the least resourced (Lotz-Sisitka 2011); they receive the smallest budgets, partly because of their size but largely because they are seen as liabilities in terms of knowledge production in comparison to other departments and faculties in universities that conduct more research. In some universities, the student–computer ratio available in computer labs is about 25 students for one computer station in teacher education departments whereas in science and mathematics departments, it can be as high as five students to one computer station (Walker 2020). The implication is that teacher education departments are unlikely to attract adequate finding to keep pace with the technological and digital developments outside.

☐ Student quality in teacher education

Teacher education departments generally recruit students from the lower end of the performance matrix at the matric entry level. Teaching thus remains a low-status professional qualification in universities compared to the more sought-after qualifications in law, medicine and engineering. Unless they perform exceptionally well in their undergraduate studies, teacher trainees have reduced chances to continue with postgraduate studies. This could limit the growth of research in teacher education in the long run and thus limit its contribution in the more knowledge-based 4IR-driven environments.

☐ Lowly motivated teacher trainees

Some studies show that teacher training is mostly a second or third option when students apply to enter university (Maringe 2006). They choose teaching as a last option, rather than as a priority and are always waiting to seize the next opportunity to leave. They also use their registration as a waiting room in case openings arise elsewhere in the university. Studies also show that, despite the altruistic, value expectancy and various intrinsic motives (Low et al. 2017), students consider future rewards associated with their careers above these other factors (Moran et al. 2001). This could have implications on their application and commitment to teacher training and to the extent to which they may commit to permanence in driving change and innovation and to contribute to knowledge production in teaching (Kyriacou & Coulthard 2000).

■ Understanding the 4IR discourse within the previous revolutions

Throughout history, the world has been into industrial revolutions that have been seen to transform our societies. The first, second and Third Industrial Revolutions (3IR) might not have been the same as the 4IR, but they were very significant during the time when they occurred. Schwab (ed. 2016) therefore argued that there are four distinct periods of industrial revolutions including the one, the 4IR which we have just entered into. For Schwab (2017:6), industrial revolution involves 'the appearance of new technologies and novel ways of perceiving the world [that] triggers a profound change in economic and social structures'. The previous three industrial revolutions are presented in Table 1.1.

Schwab (2017) further argues that the 4IR builds and extends on the digital revolution of the 3IR; thus, he contends that:

> [*D*]igital technologies that have computer hardware, software and networks at their core are not new but in break away with the Third Industrial Revolution, they are becoming more sophisticated and integrated and are, as a result, transforming societies and the global economy. (p. 7)

TABLE 1.1: Summary of the industrial revolution during the three previous ages.

Variables	First Industrial Revolution	Second Industrial Revolution	Third Industrial Revolution
Year	1760–1840	1880–1930	1960–1990
Event	Construction of railroads	Advent of electricity	Advent of the Internet
Production	Mechanical production	Mass production	Automated production
Invention	Invention of the steam engine	The age of science	Mechanical analogue electronics to digital electronics transformation
Beginnings	• Beginning of globalisation • Used water and steam power to mechanise production	• Beginning of electrification • Used electric power to create mass production	• Beginning of information technology • Used electronics and information technology to automate production

Source: Adapted from Schwab (ed. 2016).

Given this, it is therefore crucial to acknowledge the fact that the 4IR involves a massive systemic change across sectors and human lives. The higher education sector is not an exception and there is a call for new ways of teaching and learning in the new era. Whether higher education systems are doing it well or not have a huge impact on students' experiences. A description of the 4IR is needed to shed light as to why it is likely to pose challenges or opportunities for the experiences of students in higher education.

Conceptualising the 4IR

According to Ruminar and Gayatri (2018), the 4IR marks the advent of digital revolution that is characterised by the fusion of digital technologies. This involves the amalgamation of technological advances in 5G, AI, robotics, advanced materials, 3D printing, quantum computing, blockchain and several other technologies. The 4IR does not only involve massive systemic change or prolongation of the 3IR but is also characterised by a high-speed rate in development and implementation of technology in all spheres of human life (Kayembe & Nel 2019). Schwab (ed. 2016) argues that three factors that distinguish the 4IR from the 3IR are velocity, scope and systems impact. It is characterised by IoT, cyber–physical systems, Internet of services and smart factory (Erboz 2017). Other components involve AI, three-dimensional (3D) printing, robotics, blockchain technology, cryptocurrency, quantum computing, nanotechnology and bioengineering (Kayembe & Nel 2019). The 4IR also involves the use of information and communication technology (ICT). Just like any other component, ICT is used in business, government, education and civil society organisations. Table 1.2 gives a description of some examples of technological advancement prominent in the 4IR.

The development of advanced technology as shown in Table 1.1 indicates that technology may replace the human workforce with automation occurring in several fields. In fact, the reduction of job offers in different sectors can be

TABLE 1.2: Summary of the characteristics of the technological advancements in the 4IR and their descriptions.

Technological advancement in the 4IR	Description
Artificial intelligence	Involves developing computer software to complete tasks which would otherwise require human intelligence (Saleh 2019).
Robotics	Programmable machines which are usually able to carry out a series of actions autonomously, or semi-autonomously (Saleh 2019).
Blockchain technology	The name originated from its structure, where individual records, called blocks, are connected together in single list, called a chain and each transaction added to a ledger which is validated by multiple computers on the Internet (Fanning & Centers 2016).
Quantum computing	Performance of calculations by computers based on the probability of an object's state before it is measured (Dyakonov 2012).
Nanotechnology	This involves studying and applying extremely small things across all science fields, such as chemistry, biology, physics, materials science and engineering (Dyakonov 2012).
Internet of Things	The ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Kamaruzamania et al. 2019).

4IR, Fourth Industrial Revolution.

seen as a starting point towards this practice. Thus, we argue that the 4IR brings about a paradigm shift in different facets of life particularly in education. We agree with Kamaruzaman et al. (2019) who argue that there are high rates of unemployment amongst graduates because their skills no longer meet the skills required for the jobs in the 21st century. Thus, we further argue that universities should teach a set of skills relevant in both the 21st century and 4IR settings.

Applications and influences of technological advancement in higher education

Artificial intelligence

Hinojo-Lucena et al. (2019) argue that AI contributes to changing higher education structures in at least four of its aspects which include tasking the computer to perform the administrative tasks within teaching and learning; deploying software programs that are designed to cater for individualised learning; assisting students beyond the classroom, and adapting new content and methods that support teaching and learning.

Hinojo-Lucena et al. (2019) further argue that intelligent tutors and intelligent teaching systems are distributed over the Internet within AI. In this case, intelligent tutors guide the students as they learn by discerning how far the students have learnt based on their content knowledge and personal attributes. Another characteristic of AI is that it favours distributed ways of teaching and students collaborate and interact through software programs. Three techniques of using AI in higher education are highlighted further.

Artificial intelligence provides the opportunity for effective teaching and learning by providing a fully trained virtual teacher who can make teaching and learning happen at any time and place. There is therefore a need to develop three techniques of AI in higher education namely individualisation systems, intelligent robots and semantic webs (Hinojo-Lucena et al. 2019).

Robotics or automation

Aoun (2017) argues that robotics and AI are technological advances that are displacing almost all white-collar jobs. He argues that robotics and AI can perform many human tasks like climbing stairs, opening doors, analysing stocks in financial stock markets, working in factories, finding parking spaces and advising oncologists, only to mention a few. Not so long ago, technological automation was seen as a threat to low-skilled jobs, but now even other high-skilled jobs like pursuing legal research, analysing data and interpreting medical images fall under the professions that can be efficiently and effectively performed by machines (Aoun 2017).

Aoun (2017) argues that three skills are essential to make higher education (HE) graduates survive in this digitised world and these can teach them how to invent, to create and to discover and equip them to meet societies' needs which cannot be performed by any AI agent. He further argues that for human beings to be relevant in the workspaces, we now need what he called a 'robot-proof' kind of education. For him, this kind of education goes beyond 'topping up students' minds with high-octane facts' but it further 'calibrates them with a creative mindset and the mental elasticity to invent, discover, or create' things useful to the society (Aoun 2017:45). He therefore suggested a framework for a new discipline namely 'humanics' and this will allow the use of innate strengths and equip HE graduates to operate in labour markets in which they work along with intelligent machines rather than compete with them (Aoun 2017). Teaching the following skills might be useful for HE (Aoun 2017:45–46):

- 'Data literacy' – involves managing of 'the flow of big data'.
- 'Technological literacy' – involves knowing how machines operate.
- 'Human literacy' – involves teaching and learning about 'the humanities, communication and design to function as a human being'.

Blockchain technology

Blockchain has been widely defined as a digital ledger or a data base that is distributed over a network (Turkanović et al. 2018). It aims to create a 'decentralised environment where no third part is in control of the transactions and data' (Yli-Huumo et al. 2016:20). Moreover, 'blockchain

technology is flexible, secure and resilient because of its high storage capacity and resource sharing on a global scale' (Palanivel 2019:125). It has been useful in many ways because of its benefits in 'distributed data storage and the possibility of audit trails, decentralised architecture, offering security, anonymity, longevity, integrity, transparency, immutability and global ecosystem simplification' (Turkanović et al. 2018). Using blockchain technology may be a significant starting point for HEIs to create and own a 'globally trusted, decentralised higher education credit and grading system that can offer a globally blockchain-based higher education credit platform for students' (Palanivel 2019:126). In other words, blockchain technologies could be a safe and reliable data storage application in HE; accessible to authorised beneficiaries and providing authentic and reliable data.

Quantum computing

This is an area of computing, which to a great degree focusses on 'developing computer technology-based on the principles of quantum theory' (Martonosi & Roetteler 2019). Quantum theory explains the behaviour of energy and material on the atomic and subatomic levels (Preeti Padma 2020). It is a contemporary approach in which scientists tackle 'high complexity or seemingly intractable problems by complementing classical computing with a fundamentally different compute paradigm' (Palanivel 2019:127). Through this technology, lasers, transistors and many other significant machines we rely on today are operated. Because of this, quantum computing is expected to revolutionise various sectors (Martonosi & Roetteler 2019). For example, in medical health, it is expected to perform diagnosis. Likewise, in education, quantum-driven algorithms may improve student learning and curb their deficits in learning. Higher education institutions should therefore begin to pick out and be aware of the learning challenges that our local computers cannot sufficiently address. For example, it may involve training on visualising adaptive learning models in which the power and speed of quantum computing may best serve the individualised needs of our students (Martonosi & Roetteler 2019; Schroeder 2019).

Nanotechnology

This technology advancement involves 'the manipulation of materials on an atomic or molecular scale specially to build microscopic devices such as robots', as it allows the placement of atoms as though they were bricks (Bhushan 2017:10). Therefore, 'nanotechnology will give us complete control over the structure of matter, allowing us to build any substance or structure permitted by the laws of nature' (Bhushan 2017:10). However, in nanotechnology we deal with things we cannot see; hands-on and online resources become

the highest priorities in teaching. Bhushan (2017) further argues that 'nanoscience is on the cusp between the sciences'; this means nanotechnology as an interdisciplinary field breaks the barriers between the disciplines (Bhushan 2017:14). It might be useful for universities to harness the potential in nanoscience that unites different disciplines in utilising input from different disciplines in solving the world's different challenges.

Internet of Things

This describes the network of physical objects around the world that are now connected to the Internet (Hinojo-Lucena et al. 2019). These physical objects can collect and exchange data in real time using embedded sensors. The purpose of the IoT is to have devices that self-report in real time, improving efficiency and bringing important information to the surface more quickly than a system depending on human intervention (Hinojo-Lucena et al. 2019). The authors of this book provided examples that include laptops, tablets, thermostats, cars, light, refrigerators and more appliances that can be connected to the IoT. We experience the rapid change of how business is run worldwide, and the education sector is not an exception. Higher education and research are also being gauged by possibilities offered by the IoT. Thus David (2018) argued that IoT has the potential to capacitate the universities to build educational spaces 'with mixed virtual-plus-reality environments for learning intelligently' (David 2018:5). The sense of being there brought by this technology may enrich both students' and the teachers' learning experiences.

Teaching the 21st-century skills

Does it promote higher education graduates' relevance in the 4IR?

Thinking about teaching and preparing HE students for the 4IR might be a step forward in equipping pre-service teachers with 21st-century skills for future effective participation in the global economy. Skills taught should have the objective of 'reflecting [a] complex, competitive, knowledge-based, information age technology-driven society and economy' (Ama & Emetarom 2000:263). The 21st-century skills are categorised by Ama and Emetarom (2000) into three major groups. The first category comprises learning skills that involve critical thinking, creative thinking, collaboration and communication. The second category includes literacy skills that involve 'information literacy, media literacy and technology literacy' (Ama & Emetarom 2000:363). The third and last category comprises life skills and encompasses 'flexibility, initiative, social skills, productivity and leadership' (Ama & Emetarom 2000:364). Thus, we argue that HEIs may consider designing a curriculum considering the three skills categories discussed above. They may design a

curriculum that considers the three categories of skills listed above to enable them to meet the demands of the rapid change of the 4IR economies. This proposed curriculum will promote the necessary skills and competencies to increase HE graduates' employability (Butum & Nicolescu 2019). In the following section, we conclude the chapter by summarising the main argument in each of the book chapters.

Chapter synopsis

In Chapter 2, titled 'The 4IR and the practice of social justice mathematics viewed through the lens of habitus and field', Krishnannair and Krishnannair deal with the aspects from a social justice paradigm and the notions of habitus and field. This chapter proposes an extension of pedagogical habitus to the field of mathematics to form a new 'mathematical pedagogical habitus' (MPH). The central argument involves establishing a relationship between mathematical practice, mathematical practice habitus and social justice mathematics in the 4IR environment. The authors argue for placing social justice at the centre of mathematical practice viewed through the lens of mathematical practice habitus.

In Chapter 3, titled 'Preparing education students for self-directed multimodal learning for the 4IR', Olivier explores how the needs of students within the context of the 4IR depend on the different modalities of learning as well as being self-directed. For him learning involves different modalities in terms of the individual, interaction, instruction and even at the level of institutions. According to the author, multimodality will become more ubiquitous in daily life as the 4IR evolves. Consequently, the interplay of modalities within a multimodal learning context has implications for meaning-making and, by implication, learning within HE.

In Chapter 4, titled 'Transforming teacher education in the context of the 4IR through the Internet of Things and social presence', Tsakeni and Molotsi focus on two components of 4IR, IoT and social presence in the transformation of teacher education. Hence, the purpose of this study is to explore the role played by the two 4IR components in transforming teacher education as part of HE. The two components form a critical platform through which the transformation of communication and social interaction in HE becomes possible.

In Chapter 5, titled 'Teacher efficacy in the 4IR: Telling stories digitally', Babane suggests for the inclusion of a digital storytelling strategy in the Foundation Phase Language Teaching Practice curriculum. Digital storytelling is a narration of a story by using multimedia such as cameras, video recorders, computers and smart boards to enable children to voice their thoughts and emotions. This method gives children an opportunity to bring their own knowledge and

construct a cross-cultural curriculum that gives teachers a foundation upon which they can develop an inclusive curriculum, thus boosting teacher efficacy.

In Chapter 6, titled 'Re-imagining teacher professional development for the future South African public schooling context,' Kadenge argues that a parallel discussion that considers the role of teachers' professional development in response to these new dynamics is necessary. The purpose of this paper is to consider how the 4IR has and will continue to influence the role of teachers' professional development in the South African public schooling context. She argues that currently the field is imbued with various form and content challenges that make it difficult to provide meaningful experiences of teacher learning. Using a critical review of literature, this paper interrogates the opportunities and challenges of teacher's professional development in South Africa ahead of the 4IR.

In Chapter 7, titled 'Pre-service teachers' technological literacy: How ready are teacher education programmes for the 4IR?', Luckay investigates pre-services teachers' levels of technological literacy focussing on how the students 'think' about technology. The study uses a mixed-method approach, incorporating a survey, the Technological Profile Inventory, to determine pre-service teachers' conception of technology of 200 final-year student's levels of technological literacy; and probes a case of a female student who has a basic level of technological literacy. The results suggest that in general, students have a basic level of technological literacy, and therefore might struggle to integrate innovations using technology into their classroom practice.

In Chapter 8, titled 'Transforming teacher preparation for science practical work in the context of 4IR through computational thinking', Tsakeni explores the preparation of pre-service teachers to facilitate digital and computer technologies-based computational thinking through science practical work and its influence on how they conducted instructional design for practical work. She purposely selected the case of a pre-service science teacher preparation at one South African university that had embedded computational thinking in the methods course. In this qualitative, longitudinal and explorative single case study, data were collected by means of reflections generated through group work by 25 pre-service teachers as they engaged in an instructional design process of computational thinking integrated practical work. The ADDIE model guided the instructional design and served as a framework for the content analysis of the data collected.

Mutekwe examines in Chapter 9, entitled 'Transforming the school curriculum and pedagogy through the integration of social media technology in the context of the 4IR', the benefits of integrating the technology with the HE curriculum, despite the technological dilemma some academia continue to face when it comes to social media use, particularly academia who were

educated during the typewriter era. He argues that some academic members are still unsure what social media applications and technologies, for example, WhatsApp, Twitter, Facebook, Instagram, LinkedIn or YouTube, are. This chapter seeks to assess not only the receptivity levels of classroom practitioners towards incorporating social media into their pedagogical and instructional activities and their perception of its integration into the 4IR-era classroom. Adopting a pragmatic paradigm and utilising an exploratory sequential mixed methods design as the strategy of inquiry, the data to embellish the discussion in the chapter were generated through a structured and unstructured questionnaire.

In Chapter 10, titled 'Exploring pedagogy within teacher education: Embracing the 4IR', Naidoo draws attention to the future of teacher education within South Africa by showcasing examples of pedagogy for the 4IR. This qualitative, interpretive study was conceptualised using the Technological Pedagogical Content Knowledge (TPACK) framework and was located at one university in KwaZulu-Natal, South Africa. Teacher educators completed a questionnaire and based on an analysis of each questionnaire, a sample of participants were observed while lecturing student teachers. Subsequently, participants were interviewed using a semi-structured interview schedule. Thematic coding and interpretive techniques were used to analyse generated data.

In Chapter 11, titled 'The 4IR and teacher education in South Africa: Prospects for new imaginaries', Maringe and Chiramba provide a critical analysis of the key conceptual ideas of emerging discourse of the 4IR. It argues that the emergence of this discourse has the potential to influence needed transformation but the fact that it emerged from the west as an idea of transformation has the potential to exacerbate epistemic violence in the developing countries. The chapter utilises available literature to explore challenges and potentialities of the 4IR in transforming HE spaces. It ends by synthesising the evidence drawn from the chapters of the book, suggesting implications and arriving at conclusions. In particular, the chapter places emphasis on the need for further research identified across the chapters of the book and an evaluation of ways in which HE institutions need to build into their strategies, policies and frameworks for integrating the 4IR within the context of effective transformation.

Conclusion

The main goal of this book was to bring together scholars with different standpoints on the purposes, challenges and opportunities of the 4IR in teacher education. Scholarly reflections on the discourses and empirical evidence about the 4IR and teacher education are few and limited. Understanding the impact of the 4IR on teacher education, nationally and

internationally, has become critical as the world moves towards digitisation in every sector. Against this background, this book examines, from multiple perspectives, how HE in South Africa has moved the agenda of the 4IR. The first six chapters have utilised conceptual and theoretical data while the last four have engaged with empirical evidence to navigate and understand the academy. In highlighting some challenges and opportunities, the book sheds light on seven themes as listed below:

- social justice and the 4IR
- the centrality of self-directed learning
- the IoT and social presence
- teacher efficacy in the 4IR
- teacher technological literacy and readiness for 4IR uptake
- pedagogical readiness and preparedness in the 4IR
- the prospects for curricula transformation.

Synthesised evidence of the book has highlighted three fundamental challenges: it is humans, not technologies which drive change; the persistent and deepening crisis of the digital divide; a growing global digital coloniality. The opportunities of the 4IR in teacher education are highlighted as well: improved access to data and knowledge repositories; potential for sharing information in real time; drive curriculum change; use of new pedagogical approaches; innovation and new assessment practices. This opening chapter has sought to highlight some of the connections across the chapters.

Chapter 2

The 4IR and the practice of social justice mathematics viewed through the lens of habitus and field

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Abstract

Industrial revolutions have historically epitomised man's relentless material pursuits. The 4IR is no exception. The practice of teaching mathematics stands to be potentially influenced by the opportunities, challenges and demands that the 4IR entails. An unprecedented need to adapt to the 4IR-related pedagogical discourses is also felt. This chapter deals with these aspects from a social justice paradigm, and Bourdieu's notions of *habitus* and *field.* Central to this chapter is the proposition of extending the Bourdieusian notion of

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pedagogical habitus for it to be incorporated into the field of mathematics, to form the new mathematical pedagogical habitus (MPH). The central argument involves establishing a relationship between mathematical practice, MPH and social justice mathematics (SJM) in the 4IR environment. The authors thus argue for placing social justice at the centre of mathematical practice (MP), viewed through the lens of MPH. Analogous to the configurations in spacial geometry, a three-dimensional depiction of mathematical practice, MPH and SJM in space together, with the positioning of the individual practitioner in relation to these three entities, is also proposed as a tool for understanding the complex dynamics within the space of the 4IR. The role of MPH in the realisation of social justice in mathematical practice is thus visually presented and theoretically substantiated through the Bourdieusian notions within the context of the 4IR.

Introduction

Social justice mathematics, as an idea in progressive conceptualisations of educational practice, has gained traction, as seen in recent literature (Wright 2016). Its positioning in the 4IR-related discourse is worth exploring. This is because the 4IR is considered providing ideologically diverse platforms for envisaging development from both materialistic, as well as social transformation perspectives. Social justice mathematics is a concept framed to mean the field of study of mathematics in alignment with a social justice agenda built into its pedagogical and curricular dimensions. In other words, the value of social justice is considered a connecting conceptual thread between mathematics as a field of study, and the 4IR as an avenue for social transformation. This chapter dwells on this connection, tracing its roots to a sound theoretical rationale found in the Bourdieusian notions of field and habitus (Bourdieu 1990). In other words, the ideas of SJM and the 4IR are scrutinised using the Bourdieusian framework. This is with a view to considering the positioning of the practice of mathematics as an exercise in social transformation within the 4IR environment. The overarching question that the authors attempt to answer is therefore: How can the notion of SJM be theoretically positioned in relation to the practice of mathematics and the idea of the 4IR? To this end, this chapter first engages the reader in a discussion of the notions of habitus and field, followed by an effort to position the practice of mathematics within the field-habitus notion. A close look at social justice as a value, and the way in which it is positioned in the 4IR discourse, is then critiqued. This is followed by a conceptual framework that encompasses, principally, the notion of MPH coined specifically for the arguments in this chapter. The framework has SJM and MP placed in the overarching 4IR environment. The reader is also introduced to the analogy drawn from the idea of three-dimensional space, with MPH, SJM and MP considered along the three axes of x, y and z; with the practitioner being positioned in space in

relative distances from the three entities. This analogy is intended to simulate the relational positioning of the practitioner in the overall picture. The chapter then concludes with the author's observations on the merits of the formulations, and the merits of the theoretical constructs that support the formulations.

The notion of habitus

The original conceptualisation of the notion of habitus can be traced to Aristotle's idea of '*hexis*', referring to a moral demeanour that an individual attains over time (Aristotle 1998). *Hexis* has a direct bearing on the ways in which one's emotions and aspirations, and hence one's conduct, evolves (Wacquant 2016). The Latin translation of *hexis*, habitus, was popularised by Thomas Aquinas, a 13th-century philosopher. Aquinas extended the semantic scope of habitus to include a capacity for activity-based development; or a disposition situated in between the potentiality and the actuality of an action (Wacquant 2016). However, Pierre Bourdieu developed the idea further along the lines of its sociological meanings, for it to be placed on a wider platform than that which restricted its meanings by subjectivist–objectivist notions. In the same vein, Bourdieu theorised that the individual–social distinction, inherent in the notion of habitus, also becomes clear when the social structures are assimilated within the individual, leading to the creation of individual dispositions, abilities and predictable tendencies to think and act. In other words, habitus becomes an overarching 'mediating construct' that places the 'individual' and the 'social' in a mutual relationship (Bourdieu 2000:65). Within the context of *habitus*, Bourdieu thus introduces a theory of practice, telling us that practice must be understood as a relationship of a dialectical nature between habitus and the environment, constituted essentially by a set of enduring dispositions. Bourdieu considers such dispositions part of a system constituted by the totality of previous experiences, leading to an array of 'perceptions, appreciation and action' (Bourdieu 2000:261). Dispositions, in this way, help the individual manoeuvre through varied personal tasks with success, making significant use of a schematised understanding of such successes evolving from previous practices.

An individual's existence as the 'essential being', with the associated dispositional attributes, is ingrained in the idea of habitus. The practices that the individual engages in are also aspects of habitus. A teacher, for instance, can thus be said to be predisposed to particular actions and worldviews. Such actions and views are indicative of the characteristic values of the profession of teaching, with which, through the profession's own cultural conventions, teaching has come to be associated. Habitus is thus also a set of dynamic personal norms, sustained within an individual's own domain of contemplation and action, determinative of individual worldly experiences, hopes, aspirations and practices (Bourdieu 2000:78).

Wacquant (2016:66) compares *habitus* to Noam Chomsky's notion of 'generative grammar', referring to an individual's ability to extemporarily engage in rules-based, yet resourceful verbal articulation. Habitus may manifest at a practical level as a competency that is attained, preceding or with an action beyond the agent's domain of awareness. Being a social, rather than natural adaptability, which differs in its nature across references of time, place and power, habitus easily positions itself in any domain of practice that has some structural uniformity. It is the same habitus, as a natural adaptability that gives rise to the distinct personalities of the practitioners engaged in the same practice, in spite of such practice's structural uniformity. Habitus is often considered to have some degree of permanence in spite of its dynamic and evolving nature. It is, however, susceptible to changes brought about by external experiences. Once again, in line with its characteristic contradictions, habitus can also resist such influences, and hence lead to practices that are simply aligned with the social entities that created the same habitus. Interestingly, different structural layers of habitus act as a filter of successive life experiences, creating significant practice-related dispositional changes over time. The two phases of habitus, one from the past experiences that created it, and the other from the present experience that brings it into being, are thus lagged in time (Wacquant 2016:67). The manner in which habitus is governed in practice by 'sociation and individuation' is also skilfully articulated by Bourdieu (Wacquant 2016:67). Judgemental preferences of individuals and their social conduct, in general, essentially originate from society. These preferences are common to all others who have undergone the same levels of societal exposure. This is how we have habitus understood as common to collective entities, such as that in 'nation habitus' or categories of professions, such as in 'teacher habitus'. Habitus is also characterised by a degree of individuation, in that individuals, by virtue of their unique locus and identity, accumulate schemes of successful action *not* identical to schemes belonging to others.

Habitus governs the choices that individuals make, as if they (habitus) were predefined strategies, but without the structure and intentions that characterise such strategies. Habitus is not to be considered representing one particular social dimension. Rather, it is to be understood as schemata, with different structural layers that preserve and prolong the influence of the conditions under which the individual and related practice develops (Wacquant 2016). However, the habitus is not always in agreement with the social habitat in which the habitus originates. Habitus can thus lead to a discord, and hence result in practices misaligned with the milieu. It is those resistances that eventually lead to innovative social movements (Wacquant 2016:69). Habitus by itself, however, is not to be considered mechanistically facilitating nor eliciting action. Rather, habitus has to have a social world around it from which it draws actionable prompts. The agential dispositions are thus to be considered in the context of the milieu that can instil, inhibit or

redirect the affinities of the individual. This mutually constitutive influence between the individual and the milieu may result in the transformation of both. In other words, the individual, as the agential conduit of transformation, allows his practice to influence and to be influenced by the habitus. The notion of habitus thus helps us analyse social structures through the scrutiny of the social space occupied by the individual and the bidirectional relationship between the two.

The theory of field in relation to habitus

The conception of social reality as relational is fundamental to the notion of field, as put forward by Bourdieu (Hilgers & Mangez 2014). Social analysis, therefore, is focussed on the relationships that exist among the constituent entities that make up the reality, rather than the entities themselves. The notion of field has been in use in scientific and mathematical disciplines prior to its adaptation for sociology by Bourdieu (Hilgers & Mangez 2014:2). Within this conventional scientific notion of field, associated with a particular philosophy of nature, the world and the matter (i.e. the substance) that actualises the world, exist within the space–time coordinates. While change in appearance is possible, matter remains constant in terms of its quantity. However, the substance theory has been outwitted by what we call the 'field theory' (Hilgers & Mangez 2014:2). The notion of field, as an entity, is defined in terms of relations, rather than substance or matter, a system rather than objects. The 'totality of lines of force' characterises the field theory (Verene 2011:3). As its analogy in mathematics, an investigation is conceptualised around the 'relational structure of elements' and not the 'absolute property of the elements' (Verene 2011:93). The field theory negates the idea of 'absolute space–time', and hence the reference to 'individual objects'. Instead, it refers to a 'relational space–time' and a system of relations instead of an individual (Hilgers & Mangez 2014:3). By simplifying the definition, these formulations refer to a 'relational epistemology' that allows us to understand a person through their social environment. Hilgers and Mangez (2014) explain that by studying the surrounding field, one can gain an understanding of the individual's behavior. Drawing further on this analogy, just as in the physical field with lines of force, a particular pattern of the forces of relations has a determining effect on the individual situated in the social field; and hence the personal disposition or the habitus. The structural characteristics of the relations that act between the individual and the field are such that the influence is felt both ways. In other words, the dynamics of a social phenomenon are best explained in terms of the totality that involves the object of the phenomenon, and the field that surrounds the phenomenon. More formally put, the habitus is in complete accord with the field, in that both remain influential towards and influenced by each other in a dynamic and constantly evolving state of permanence (Hilgers & Mangez 2014:3).

According to Bourdieu (1998), the social world, with its divisions objectively considered, corresponds with the mental world constructed by the agents or actors of the world. Bourdieu's assumption was that there exists a relationship between actors in different fields who hold similar views (Bourdieu & Clough 1998). For instance, those who dominate a field will have a shared positionality, just as those who are dominated share identical viewpoints. The dominant actors in a field, while trying to keep the current social order in which they dominate, and hence preside over the reproduction of such dominance, do not create an impression that they are hostile to change. This is a significant observation that Bourdieu emphasises: the covert enterprise of the dominant sect helps form a discourse propagating the ideal that change is a mandatory objective that all must pursue. Those dominated will then be lured into admitting that all must be ready to make sacrifices to meet the new economic demands of competition and the challenges thereof (Hilgers 2014). The change that is proposed is thus externally sourced, as opposed to notions of change emanating from the autonomous functions of the actors themselves in the field. In this way, the change discourse, under the pretext of envisioning change, incapacitates the fields, which are otherwise self-controlled. These external forces manipulate the fields to suit the economic needs of the vested interests emanating from those forces of control. In this process, the dominant actors become even more powerful, with what Bourdieu calls the 'cultural capital' based on criteria external to the field in question (Bourdieu & Clough 1998). These external criteria have influenced the fields and the creation of norms for new practices. One example is the field of education being infiltrated with performance-measuring mechanisms (Hilgers 2014).

It is helpful to think in terms of habitus and field at the level of social practice of actors to theorise the changes that are taking place and the conditions conducive to such changes. By merging ideas, we can better understand how the change aimed at consolidating and maintaining established positions traditionally dominates the change aimed at reversing it. As a result of this merged understanding, we can also explain the fragility and short duration of the association with social transformation enterprises of dominated positions. Another aspect of this merged notion is that it helps us understand the structure of positions that constitute the social space within an autonomous domain of action, and a matrix of dispositions, resulting in its agents' schematically organised actions and thoughts (Hilgers 2014).

Within the social field, Bourdieu argues, the individual engages in actions driven by unintentional rationality; similar actions are aptly termed *reasonable* rather than *rational* and are not necessarily motivated by reason. However, field theory helps us conceptualise social change as a structural phenomenon with a high level of rigour (Bourdieu 1998:27).

The practice of mathematics teaching as an action related to the 'habitus–field' notion

This chapter has so far dealt with *habitus* and *field* as two theoretical constructs that assist in understanding how individuals' dispositional responses to prompts in the surrounding field characterise their practice. Let us now look specifically at the practice of teaching through the notions of habitus and field.

Bourdieu's theory of practice has been the subject of intense scrutiny by researchers, using it for theorising educational phenomena (Von Rosenberg 2016). Education, in line with the theory of practice, is broadly considered a habitus transformation (Von Rosenberg 2016:1487). Habitus, as 'an open system of dispositions', in itself is to be deemed a process, as Bourdieu has indicated (Bourdieu & Wacquant 1992:133). In an education context, the very nature of habitus being a process allows it to be used for its own transformation. The notions of habitus and field can thus be put to use in the matching of educational theorisations that explain the transformation of the *self–world* relationship, and a social theory that is formulated empirically to substantiate those theorisations (Von Rosenberg 2016). However, an enquiry into the social conditions that advance the cause of education, calls for theorisations beyond the limits of habitus. Societies that have inherent variances across its units are bound to have multiple unique relations among its basic autonomous units. Such complex relations can often be beyond the scope of conventional empirical verifications, defined in terms merely of habitus (Von Rosenberg 2016:1489). Therefore, a study of processes in education and such processes' social constitutions in terms of the fundamental logics with which societies function, is beyond what the notion of habitus can explain. Bourdieu therefore proposes the notion of *social field* to circumvent this difficulty (Von Rosenberg 2016:1489).

The generative and 'mutually constitutive' relationships between habitus and field are embodied in social practice (Feldman 2016:71). For example, within the field of education, pedagogical practices should not merely be construed as resulting from the educator's habitus. Rather, they should be accepted as emanating from the interaction between the habitus and the field within which the practice takes place (Feldman 2016:71). In this way, within the context of teaching, educators may adopt certain value systems and rationalities that evolve and characterise their practice over the years, integrating them with their habitus. This variant of habitus is often termed 'pedagogical habitus' (PH) (Feldman 2016:71). Owing to its generative and dynamic nature, this habitus, with its inherent set of dispositions, and its interactions with the field of education, leads to the positioning of the practitioners as belonging to particular types. The PH can be seen to originate from the teachers' own schooling experience. Such habitus can influence their

professional practice, which, in turn, reforms and consolidates the identical habitus in substantial ways. Pedagogical habitus can thus be, in certain instances, considered reproducing practices driven by certain beliefs that are deemed invariably true (Feldman 2016:72). The dispositions that underpin the habitus may, however, not be subject to alteration through purposeful contemplation. This has led Bourdieu to theorise that the transformation of a teacher's practice is a function of the formation of the teacher's PH, and his or her relationship with the social field in which the practice is situated (Feldman 2016:72).

Practice-related transformation can also be considered in the context of habitus being in discord with the structures external to the practice. Bourdieu states that it is in these discords that alternative practices are often conceptualised (Bourdieu 1990). Pedagogical experiments are often the result of such discords, which in turn leads to realignment of the PH. However, the enactment of pedagogical practice is largely influenced by the PH (Feldman 2016). In spite of its durable existence, PH is not considered eternal, meaning that it is subject to changes that can be brought about by intentional actions (Bourdieu 1990).

This chapter has so far dealt with the Bourdieusian notions of *habitus*, PH in particular, and *field*, in relation to practice, as a socially anchored idea. We now introduce the concept of the 4IR in an attempt to position social justice as an issue emanating from the inevitability of digital inequality, brought about by the overarching phenomenon of the 4IR. The Bourdieusian notion of field and habitus, and hence MPH, will then be used as a lens to view the socially just mathematical practice aligned with the notion of the 4IR.

The 4IR and social justice

Klaus Schwab (2016), in his influential book titled, *The Fourth Industrial Revolution*, talks about the origin of the notion of the 4IR in relation to the previous industrial revolutions. During the World Economic Forum Summit at Davos (Switzerland) in 2016, Schwab called upon the global community to prepare a concerted educational response to the demands of the 4IR. He cautioned that the world needs to have a unified narrative that addresses the transformational potential of the 4IR and, more importantly, that creates an enabling and inclusive environment for individuals and communities not necessarily prepared to benefit from the 4IR (Konstantin & Vladimir 2017). Naming of the idea of an industrial revolution as the '4IR' has helped 'catalyse action', aimed at preparing a holistic response to the social, scientific and educational demands of the 4IR (Thomas & Nicholas 2018:20). A discourse has since been created around this idea. The 4IR's implicit relation to neoliberal capitalism has been specifically of interest to researchers (James 2018). The power of technology that has been brought in by the 4IR on an unprecedented

scale, is also seen as a catalyst for social transformation (James 2018:341). The 4IR's influence on society and its relational structure is also well-acknowledged (James 2018:356).

Industrial revolutions have generally been influential in terms of their social and educational transformative power (Bryan 2018). The power to transform lives in unprecedented ways is a characteristic aspect of the 4IR, brought about by technological advancement and the associated 'shifting of economic power' (Bryan 2018:219). Transformation of the type of employment and the ways in which employability is defined, rather than the loss of employment opportunities, will be another aspect of the 4IR (Nguyen, Le Quang & Nguyen 2017). A portion of the workforce is likely to be out of work, owing to a lack of acceptable 4IR-compatible credentials, such as technological proficiency of an advanced nature (Nguyen, Le Quang & Nguyen 2017:30). This may lead to an emergence of a displaced category of workers trying their luck in one type of job after another, raising significant social justice-related issues. In other words, from a social justice perspective, the 4IR may lead to the exclusion of a section of the society from mainstream economic activities. This would result from a widening gap between those with technological proficiency and those without (Nguyen et al. 2017). Added to this, the issues of income inequality resulting from the polarisation of society along the lines of access to financial resources and gender inequality are likely to negatively impact ordinary citizens.

An interesting aspect here is that 'change' seems to have a ubiquitous significance in the context of the 4IR and education. While the advent of the 4IR was preceded by an educationally enhanced awareness and a quest for increased quality of life, the 4IR, in turn, seems to demand the very idea of education having a 'relevance-related' paradigm shift. An increased emphasis on scientific and technological empowerment of students, both at the level of disciplinary expertise, and at the levels of associated disciplinary literacies, is noticeable. This distinction manifests in, for example, the mathematical sciences, where increased participation from the student community is emphasised. This can be seen against non-mathematical disciplines, where mathematical proficiency at the levels of scientific and mathematical literacy is emphasised. This scenario characterises, at a very technical level, the shift towards the relevance-related paradigm that the 4IR has brought about. While content relevance is at the core of transformation, for education to be aligned with the demands of the 4IR, a 'socially-just' approach is imperative. This is because of the paradoxical centralisation of wealth and power that comes with people's increased access to these entities, both being opposing ideas in their conventional sense (Bryan 2018). In other words, socially just affordances of the 4IR, underpinned by values of equality of opportunity brought about by the empowerment of the historically marginalised, are central to educational practice. This highlights the need for us to have a 'socially-just mathematics'

as an alternative conception in disciplinary mathematics. A detailed treatment of 'SJM' as a disciplinary derivative of the social justice paradigm concerning teaching mathematics to previously marginalised communities is not in the purview of this chapter. However, it is essential for the reader to keep in mind the idea of SJM considered in the context of 4IR-related imaginaries. This is because the practice of SJM at a pedagogical level is central to this chapter, as observed through the lens of a PH. In other words, the dispositional aspect of instruction has a bearing on the practice of socially just mathematics in the 4IR environment. Therefore, PH and social justice are notions that are conceptually linked at their abstract and practical levels through the practice of mathematics, all considered in the 4IR environment. In this connection, we now look in more detail at the practice of SJM, before we attempt a description of this conceptual configuration and its implications.

The notion of social justice mathematics in the context of 4IR

The notion of SJM as a movement in pedagogical discourses can be attributed to Eric Gutstein (2005). This notion essentially envisages teaching and learning mathematics in ways that help the practice (i.e. the teaching and learning). The participants in that practice should rise above gender, class and race confines. SJM involves an awareness that acts of social injustice perpetrated against certain sections of society are central to mathematical practices. Such practices, then, should be driven by a set of 'social justice pedagogical goals' and a set of 'mathematical pedagogical goals' (Gutstein 2005:23). These goals are formulated to inculcate the values of equality and justice as part of an effort to make education a vehicle for social transformation. In this way, the idea of SJM has come to be referred to as constituting a social transformation discourse, as well as an entity that embodies educational inclusivity as a fundamental value. The first dimension envisages curricular and instructional integration of social justice issues with the practice of mathematics that should culminate in the creation of increased awareness of such injustices. The second dimension involves making the mathematics knowledge domain accessible to all sections of society; irrespective of race, gender or financial status.

Maintenance of power imbalances and the reproduction of such a social order have been part of schooling for a long time (Bourdieu & Clough 1998). Linking mathematical ability to natural giftedness, as opposed to an exposure to an empowering and supportive mathematical environment, was practised as part of this agenda (Wright 2016). Social justice mathematics, in this context, calls for the creation of mathematical power and students' agency in socially transformative activities. This should help students become aware of injustices; and translate that awareness into action aimed at the transformation

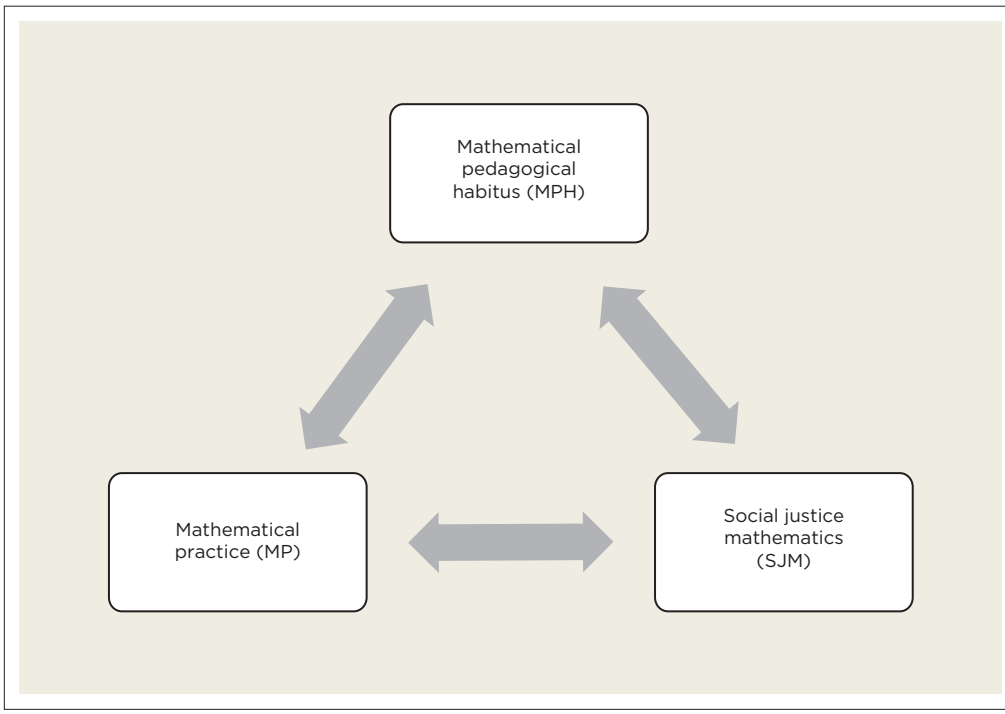
of society as a whole. The mathematical power thus attained should involve an ability to critique the nature of mathematics, and the ways in which it is afforded a status deferent, and often superior, to other domains of knowledge (Wright 2016:107).

The 4IR happens to be an environment in which SJM assumes relevance. This relevance manifests at two levels. The first is at the level of people's empowerment in terms of skills and competencies directly related to or derived from a set of earned mathematical competencies. Mathematics being a key discipline in this context, the proficiency in it is fundamental to a variety of scientific, engineering and technical knowledge and skills. It thus becomes the gateway area of knowledge that guarantees access to training in skills and competencies aligned with the demands of 4IR as an employment avenue. The ubiquitous application of mathematical skills and knowledge to mathematical and non-mathematical contexts reinforces its relevance as an area of study. The 4IR, with its convergence of cyber–physical systems, and the associated interdisciplinary nature of skills that it demands from potential jobseekers thus places mathematics at the centre of all employment-focussed learning and training. The social justice dimension of mathematics as a field of study is thus explicit, in that it becomes an instrumental factor that ensures people's access to the benefits of the 4IR. The second level at which SJM aligns with the 4IR is by way of both being platforms for emancipation and furthering of the values of justice and equity. The 4IR offers technological advancement with the potential to change the lives of millions of marginalised people; while it has the potential to be exploited by vested interests, much to the disadvantage of the same marginalised people. From a social-upliftment point of view, however, the 4IR and SJM are potential avenues that can be linked by the practice of mathematics for the purpose of upholding social justice as a basic imperative.

The social field of mathematical practice – towards a conceptual framework

This chapter now focusses on presenting the conceptual framework that served as a connecting logic apropos of the ideas presented, and the concluding propositions. The purpose here is therefore to position each concept in relation to the others in the broader context, clarifying the rationale for having such concepts for the collective sense-making. Figure 2.1 is presented with this intention. The constructs of MPH, SJM and MP, and the bidirectional relationships among them, are presented in Figure 2.1. This is proposed as depicting the 4IR environment in which all the concepts are considered placed.

'Mathematical pedagogical habitus', a term coined to depict the Bourdieusian notion of PH, is central to this conceptual framework



Source: Author's own work.
FIGURE 2.1: The social field of mathematics in the 4IR environment – a conceptual framework.

(Bourdieu 2005). Habitus, according to Bourdieu (2005), is the functional manifestation of a lasting system of dispositions characterised by the particular ways in which individuals exist, perceive, function or contemplate. Such dispositions often become embodied in actionable schemes in a state of dynamic permanence. Bourdieu theorised that habitus helps us understand our practice as relationally constituted within the idea of a social field (Feldman 2016). The habitus is systematically related to one's past experiences and the situations through which one passes presently. The habitus–field relationship is of a dialectical nature, in that both are subject to transformation as a result of this passage. In the framework here, the social field of MP is considered situated within the larger context of the 4IR. The notion of field, the field of MP in this case, is also of a fluid nature, in that, just as with the habitus, the field is also in the process of being constantly made and unmade. The teachers' pedagogical practices are not solely the manifestation of one's habitus. Such practices are best considered resulting relationally from an interaction between the habitus and the field. This allows teachers' practice to be in a generative interaction with the surrounding field to which the practice is linked in a mutual relationship. The teachers' PH is thus constituted by dispositions derived from characteristic value positions that the fields helped them

(the teachers) imbibe. The notion of MPH, therefore, is a theoretical extension of the PH considered in the field of mathematical practice. Mathematical pedagogical habitus helps us position teachers' habitus as the single most important aspect defining the MP. This is because habitus, as formulated by Bourdieu, is a powerful conceptual tool explaining the relational intricacies of practice. Habitus, when placed in the context of mathematical pedagogical practice, then provides us with a robust explanatory grounding for us to consider MP, as embodied in the teachers' repertoire of dispositions.

We now need to look at how the framework establishes the link between MPH, mathematical practice and SJM, as interconnected entities in the larger context of the 4IR. The 4IR, and the ideologies implicit in its varied manifestations in the lives of the ordinary citizens, is the rationale central to the relational conceptualisation of the framework. In other words, the 4IR, as the overarching environment, demands a particular set of mathematically oriented pedagogical dispositions from the practitioners. According to Bourdieu's theorisations, such dispositions influence and are influenced by the practice. In the context of such influences, the notions of SJM assume relevance. A socially just MP is ideologically well-aligned with the values that should drive the agenda of the 4IR. This is because the 4IR has inherent social justice issues that may lead to it sidelining a significant section of the world population through 'the separation, isolation and exclusion in the society' arising from an inability to catch up with the demands of the 4IR (Nguyen et al. 2017:30). Education, and SJM education in particular, then, has the potential to safeguard and promote the values of equality and justice that should foreground the 4IR as a transformative technological event. Mathematical pedagogical habitus is thus strategically placed to influence social justice MP, which, in turn, has the potential to reorient practice towards embracing values of justice and equality.

The clockwise and anticlockwise directions in which the influential relations are considered are also significant, as Figure 2.1 indicates. This results from the bidirectional relationship among the three entities. The argument here, therefore, is that an understanding of the complexity of the relationships is essential for practitioners to position themselves as active participants in the 4IR. Having the practice of SJM under the field of view of habitus and field as theoretical lenses, under the overarching umbrella of the 4IR, has its merits. Such a placement has helped us establish the fact that the idea of PH needs to be theoretically extended for it to evolve into the notion of MPH. Mathematical pedagogical habitus, and its underlying Bourdiesian philosophy of relational dispositions, will then serve the purpose of viewing SJM and its practice. This view is then considered in relation to the 4IR's educational expectations; and hence, the educational responses to such expectations. As to how SJM does or does not become a natural constituent of the MPH, such is an issue best viewed through the lens of habitus and field.

By way of a concluding proposition, this chapter now introduces an analogy from the three-dimensional geometry for the special positioning of these constructs. Such is for ease of visualisation of their combined existence. Within the three-dimensional space of the 4IR environment, MPH, MP and SJM can be arbitrarily placed, with MPH along the *x*-axis, SJM along the *y*-axis and MP along the *z*-axis. The teacher can then be considered positioning himself or herself within the three-dimensional space, analogously representing the 4IR environment. This positioning is then considered relationally constituted by MPH, SJM and MP, just as a point in space is defined with reference to the three coordinates. This analogy also helps us visualise the teacher as an entity, three-dimensionally coordinated or held in position by the three constructs MPH, SJM and MP. Within the 4IR space, the teacher's relative positioning determines, and is determined by, the varying positions (values) of MPH, SJM and MP, considered along the three axes. In other words, any practitioner positioning himself or herself at a particular point within the 4IR three-dimensional space, has a set of unique MPH, SJM and MP values (characteristics) associated with him or her. The analogy thus helps us understand the practice of SJM as an exceptionally complex extension of the mathematical practice, just as the MPH is an extension of PH, both being considered in the context of the 4IR, which, in itself, is a complex phenomenon.

Mathematical pedagogical habitus and the 4IR-aligned mathematical practice at the classroom level

This chapter has so far dealt with the theoretical grounding of SJM, prompted by the 4IR discourse, on the notions of habitus and field. However, reconstruction of the field conditions for the 4IR-related education imaginaries to flourish, is dependent on explorations that go beyond the confinements of the theory of habitus and its emphasis on the actors in the field (Von Rosenberg 2016). It is therefore worth considering how MPH and 4IR-aligned mathematics will influence classroom practice. Mathematical pedagogical habitus, in its true sense, cannot be representative of a single pedagogical structure or norm. Rather, it is the layered sets of schemes that precipitate the environmental influences to which the practitioner has been exposed (Wacquant 2016). This translates to, for example, the mathematics classroom practitioner accumulating exposure to the social justice realities inside and outside the classroom, resulting in assimilation into MPH. Therefore, the fundamental issue becomes the reorientation of MPH towards an acknowledgement of the social justice realities compounded by the demands of the 4IR-related education discourse. If MPH is in a dynamic state of permanent reconstitution, the factors that influence its orientation towards a

socially-just mathematics at the level of classroom practice should become the preferred pedagogical imperative. Mathematical practice should, thus, become the platform on which habitus transformation, as Von Rosenberg (2016) puts it, may lead to acceptance of social justice as an educational imperative.

Deriving from the original formulation of habitus transformation, MPH can also be understood as a system of internalised organisations that facilitates the act of perceiving and drawing clear distinctions between what is proper or improper, or what is moral or immoral, in the context of mathematical pedagogy (Bourdieu 2005). Bourdieu also makes it clear that habitus, and MPH by extension, does not merely stipulate a blueprint for actions; rather, it is considered resulting from the individual–environment interface. At the level of a practitioner who is constantly exposed to the external world of the classroom, he or she will eventually internalise the needs of the classroom constituting the habitus. The habitus, resulting from adapting to the field, thus orients the practitioner to expect the future to be in line with the immediate past. This further results in the individual preserving previously attained abilities, tendencies and predilections. Bourdieu (2005) also tells us that habitus, by its very nature, is resistant to change, which, in the case of MPH, translates to the practitioner clinging on blindly to previously held practices. This has special significance in the case of an individual's MP being radically transformed, leading to a breakaway from the past. Such adaptations are significant in that they change the very nature of an individual's practice-related identity. In other words, transforming one's MP to suit the demands of the 4IR and its social justice connotations, is fundamentally a question of the teacher's professional identity.

Mathematical pedagogical habitus can also be considered constituted by teachers' 'embodied cognitive, dispositional and corporeal' mathematical pedagogical preferences that eventually become the teachers' 'primary habitus' (Feldman 2016:71). Mathematical pedagogical habitus is not a set of responses that a practitioner is pre-equipped with. On the other hand, it is the dispositions which interact with the social field of mathematics teaching, in a bidirectional relationship. Built into this MPH will be 'social and cultural messages' from the field of mathematics teaching, that directly place teachers in certain categories of practitioner (Feldman 2016:71). Such placements, in turn, act on them, transforming them into taking up certain positionalities with regard to approach and personal philosophy of teaching, in general. If SJM – which is aligned with a 4IR-compatible pedagogical organisation – is considered an aspect of such a philosophy, and if it is to materialise in the classroom, MPH should lend itself to being transformed to suit such educational aims. Classroom practice will then cease to become reproductive mechanisms of educational injustice, which may previously have been accepted as moral

acts, into the repertoire of practitioners' dispositions. However, MPH, as Bourdieu (2005) noted in the context of habitus, is not easily susceptible to purposeful transformation. MPH will only respond to such transformational efforts over time, just as habitus formation takes place over time. This means that a predilection to social justice cannot be forced upon individuals. Rather, such a predilection is a quality of the PH which is best left to itself to evolve into its explicit classroom manifestations.

Mathematical pedagogical habitus as a theoretical lens to view the practice of teacher education needs to be mentioned here as well. Bourdieuan notions of field and habitus have been extensively referred to in teacher education discourses (Hooley 2013). The essence of field theory, according to its Bourdieuan conceptualisations, affirms the importance of 'structure and agency' and the relationship between them as manifesting in the practice of teacher education (Nolan 2012:203). This author uses the phrase 'prospective teacher agency' to underscore the need for ideations in defence of embracing progressive notions in teacher education as an attempt to re-define its practice based on the quality of agentiveness (Nolan 2012:203). MPH formations can be considered in the context of this re-definition of practice with which 'prospective teacher agency', as proposed by Nolan (2012), aligns itself. This proposition also aligns with the idea that purposeful changes in the pre-service teachers' learning experiences have the potential to transform their PH in significant ways (Mills 2013). Such changes foreground the notion that particular practices are often shaped by a professional consciousness that falls outside the realm of the 'rational calculation' of practitioners (Mills 2013:44). A set of profession-related dispositions that constitute this consciousness, and by extension the MPH, are therefore best considered existing beyond the confines of time and space (Bourdieu & Wacquant 1992). However, MPH, just as the Bourdieuan notion of habitus, allows itself to be transformed through purposeful action. It is at this point that teacher education as a platform for MPH formation holds the power of agentiveness in pedagogical transformation.

Conclusion

This chapter has attempted to contribute to the theoretical debate on the idea of SJM and its placement in the 4IR environment. The guiding question was formulated around the issue of SJM conceptualised as placed in relation to the 4IR discourse and the practice of mathematics. The Bourdieusian notions of habitus and field provided a strong theoretical frame on which to conceptualise the positioning of SJM in relation to the 4IR expectations on educational practice. As an extension of the existing theory on PH, the formulation of the idea of MPH helped position mathematical practice as a constituent component in the 4IR discourse. Mathematical pedagogical

habitus, as a theoretical extension of PH, as proposed here, is hence considered the most influential factor linking SJM with the practice of mathematics in the 4IR environment. In other words, MPH is theorised as having a critical role in envisioning the attainment of social justice through mathematical practice. This leads us to the proposition that the ways in which dispositions help evolve practice, and the ways in which practice helps evolve dispositions, are keys to the ways in which habitus, as the collection of such relations, evolves. This has implications for observing teachers' practice from a social justice paradigm. Finally, an analogy of these three constructs being placed along the axes *x*, *y* and *z* in the three-dimensional space of 4IR is presented to elucidate the complex relations that determine the constantly evolving positioning of the practitioner in the 4IR environment. The notions of habitus and field, together with the idea of the newly proposed MPH, thus have the potential to be a framework for further exploring the intricacies of this complex scenario.

Chapter 3

Preparing education students for self-directed multimodal learning for the 4IR

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Abstract

As the Fourth Industrial Revolution (4IR) implies the blurring of lines between digital and other spheres of life, education students should be adaptable and self-directed. This chapter explores how the needs of students within the context of the 4IR will depend on the different modalities of learning and being self-directed. Learning involves different modalities in terms of the individual, interaction, instruction and even at the level of institutions. Within the context of the 4IR, multimodality in more aspects of daily life will be ubiquitous. Consequently, the interplay of modalities within a multimodal learning context has implications for meaning-making and, by implication, learning in HE. Building on the scholarship of multimodal learning provides a

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framework for understanding how the fusion of modes function in education. In addition, the 4IR requires students to be adaptable and able to take charge of their own learning in order to become self-directed and lifelong learners within the dynamically changing HE environment. In this conceptual chapter, the theoretical principles of self-directed multimodal learning are interrogated in the context of the 4IR as have been identified in the scholarship in these fields. Practical steps are proposed for preparing students in teacher education for self-directed multimodal learning.

Introduction

Teacher education has always existed in a dynamic context (cf. Heck & Ambrosetti 2018; Smith 2017) where change has been inevitable and intertwined with societal progress and adaptation. However, challenges such as the COVID-19 pandemic and the encroaching Fourth Industrial Revolution (4IR) have had a distinct impact on teacher education. The current nature of HE may seem problematic because, according to Gleason (2018), it was constructed within the context of earlier industrial revolutions in mind and that changes in HE have been slow. Yet, adaptation might be necessary, and the 4IR might necessitate more in-depth and rapid change. Furthermore, it is acknowledged that every generation has a unique experience that is influenced by their contexts (Seemiller & Grace 2019). As such, tomorrow's teachers and lecturers are already moulded within a technology-enhanced and knowledge-overloaded society. This new context requires sensitivity towards its unique multimodal nature as well as an increased need for adaptable, lifelong and self-directed learners.

Klaus Schwab (2015) coined the term 4IR and this revolution can be interpreted within the context of the first three industrial revolutions (Strydom & Prinsloo 2020). In this regard, Schwab (2016) explains the first three revolutions in the following manner:

> The First Industrial Revolution spanned from about 1760 to around 1840. Triggered by the construction of railroads and the invention of the steam engine, it ushered in mechanical production. The second industrial revolution, which started in the late 19th century and into the early 20th century, made mass production possible, fostered by the advent of electricity and the assembly line. The Third Industrial Revolution began in the 1960s. It is usually called the computer or digital revolution because it was catalysed by the development of semiconductors, mainframe computing (1960s), personal computing (1970s and 80s) and the Internet (1990s). (p. 11)

Education also changed accordingly as society and technology adapted to the needs and opportunities provided by these revolutions. Klaus Schwab (2015) claims that this 4IR could 'fundamentally alter the way we live, work and relate to one another' and that it 'is characterised by a fusion of technologies that is blurring the lines between the physical, digital and

biological spheres'. Consequently, future teachers need to navigate a context where the borders between digital and other aspects of life are not so clear. Hence, this revolution is not limited to technological advances but also implies a change as to how society interacts.

The sudden forced digitisation of all levels of education because of the COVID-19 pandemic shows how external factors can make other modes of interaction prominent and at times occur at a very fast pace. Heck and Ambrosetti (2018) make the following observation on teacher education and change:

> Teacher educators are more often than not at the battlefront of change and thus are immersed in the uncertainty that change in policy creates. They implement change in and through initial teacher education programmes that consequently explicitly impact the pre-service teachers enrolled in those programmes. In this respect, they also inexplicitly impact schools and in-service teachers and the role that they play as pre-service teachers undertake professional experience. (p. 4)

Consequently, teachers themselves must be adaptable and as self-directed learners be able to acquire what is needed for the changing environment. As teachers also function at the vanguard of change, they will have to facilitate learners' adaptation to the rapid changes brought on by the 4IR. A key step in this process is to adequately prepare student teachers to be equipped to handle such circumstances and therefore not only be prepared for a specific aspect of the dynamic educational context, such as certain instructional technologies, but rather be prepared to be self-directed in their approach to change and be able – as lifelong learners – to unlearn and relearn (Toffler 1971) as necessary.

Moreover, an extreme view of education in the 4IR is illustrated by Johannessen (2019) as it is regarded that robots and holograms could replace teachers as he envisages the robotisation of the work done by knowledge workers. Such a viewpoint, on the one hand, makes any scholarly discussion about human teacher education a futile exercise; on the other hand, it prompts academics in the field to reorientate themselves and focus on creating efficient learning algorithms rather than creating efficient teachers. Teachers and by implication also those in HE tasked with training teachers need to consider how this reorientation towards what can or rather should be automated and how teachers can be prepared to focus on affectual aspects of learning or even contribute to differentiation and support.

Changes in the education sector associated with the 4IR should also be considered in light of existing problems. This is expressed by Taylor (2019) as follows:

> Addressing the knowledge backlogs of hundreds of thousands of teachers currently in the system will remain an urgent task for years to come. But until we ensure that new teachers are sufficiently knowledgeable, skilled and prepared to face the realities of working in South African schools, the problem will extend into perpetuity. (p. 274)

Therefore, a focus on not only knowledge and skills for teacher education but also situating such learning to reflect the realities of the profession is increasingly important. However, these realities will not remain untouched from the effects of the 4IR. Hence, this dichotomy of addressing existing social and historical challenges and attending to emerging needs related to the 4IR will determine how planning and management of the teaching profession and training enterprise will be conducted.

The teacher education predicament is also clearly described by Chisholm (2019), who states that it is increasingly required from teachers to prepare learners to interact and engage with a world that is infused and changed through technology. The key here is the idea that circumstances are and will be constantly changing and not just in terms of technology. This aspect implies that not only school learners and university students but also school teachers and university lecturers should be adaptable. Therefore, being an adaptive self-directed learner and being sensitive to different modalities are essential for all role players in the education sector (cf. Selvi 2011).

According to Schwab (2016:92), being adaptable is essential, as he believes that a radical systemic change in terms of human adaptability is imminent. This aspect also relates to the wider concept of teacher adaptability as teachers need to be able to address the specific needs from their context and learners. To this end, professional development of teachers can play an instrumental role towards addressing the need for teacher adaptability (Parsons, Ankrum & Morewood 2016). Adaptive practices also rely on teacher autonomy and their sense of self-efficacy and it is evident that teacher adaptability is linked with teacher effectiveness (Loughland & Alonzo 2018). Importantly, teacher adaptability should ultimately also translate into concrete action and classroom practices (Loughland 2019).

In this chapter, the importance of two aspects for teacher education is highlighted, namely self-directed learning (SDL) (Bosch, Mentz & Goede 2019) and multimodality (Olivier 2020a), because as described further there is a need for an increased focus on self-directed multimodal learning. In this regard, SDL is highly relevant, as Xing, Marwala and Marwala (2018) believe that the 4IR implies that lifelong training and retraining will be a common requirement for all and not merely something reserved for an ambitious few. For teachers, lifelong learning would mean taking charge of their learning. However, the concept of lifelong learning (cf. Iredale 2018) has wider implications. According to Jung (2020), lifelong learning is a vital component of the 4IR, which means that higher education should rethink its role in addressing the educational needs of lifelong learners. Selvi (2011) also accentuates the importance of lifelong learning competencies for teachers. For teachers to be effective lifelong learners will imply that they are self-directed learners and hence the scholarship of SDL is highly relevant to this discussion. However, learning is increasingly taking place in a multimodal context.

Furthermore, as regards multimodal learning, the increased use of online learning and learning technologies in general has made multimodality not only a reality at the university level but also in school and work environments. For the purposes of this chapter, *multimodal learning*, entails the use of different modes of instruction through different technologies, and opening access to learning through distance and hybrid modes of delivery and it could highlight further affordances for teacher education. Within this context, Penprase (2018) also notes that planning for the 4IR:

> [*M*]ust be built upon the results of the Third Industrial Revolution described earlier, with its emerging development of hybrid online and in-person instruction, and efficient and seamless integration of global videoconferencing and a wide array of asynchronous educational resources. (p. 219)

Therefore, it is evident that in the future, educational practices will build on existing hybrid or multimodal aspects within a context where technology is increasingly infused in all aspects of our lives, as Olivier (2020a) additionally observed the following in terms of the wider context:

> Due to the rise in student numbers, the changing nature of the workplace, and the diverse and changing requirements of the so-called 21st-century skills as well as the needs of the Fourth Industrial Revolution, education needs to prepare students to be adaptable and learning to be continuous. (p. 118)

Hence, implementation of multimodal learning efforts should aim towards fostering self-directedness among learners with the support of a range of skills and literacies that meet the needs of the educational context and the wider society. This chapter also approaches learning from a design-theoretic approach, as such an approach to learning emphasises learning as communication as well as aspects of materiality that can both create and define conditions for learning (Kress & Selander 2012:266). With this as a basis, it can be considered that multimodality infuses all aspects of the learning process.

In light of the above, this conceptual chapter aims to explore how education students can be prepared for self-directed multimodal learning within the context of the 4IR. In addition, practical steps are proposed for preparing students in teacher education for self-directed multimodal learning.

Teacher education for the 4IR

The implications of the 4IR for HE have been highlighted by several authors (Johannessen 2019; Jung 2020; Schwab 2015, 2016), as this phenomenon and its effects will potentially permeate all aspects of society. In this regard, Jung (2020) explicitly states:

> [*T*]he impact of the Fourth Industrial Revolution is significant in the higher education sector, both in research and teaching, in terms of what knowledge they create, how they train highly skilled people such as postgraduate students and what curricula they provide for undergraduate students to prepare them for their labour market transition. (p. 137)

Consequently, specifically in teacher education, such issues should be considered, as it is here that universities, according to Jung (2020), should take the lead. According to Taylor (2019:279), 'pre-service teacher education does seem to provide the optimal point at which to break South Africa's vicious cycle of school mediocrity'. Hence, improving practices in this context is of national importance, especially if teacher education lecturers are preparing students for teaching practice in the context of 4IR. Furthermore, Cooper et al. (2019) are of the opinion that the digitisation of societies could disrupt and change many aspects of our lives.

In this regard, higher and basic education will not be unscathed. With different possibilities in terms of public-, private-, home- or even virtual schooling, Seemiller and Grace (2019:190) assert that not only are different options available in terms of schools, but that there are also different learning modalities that are offered. Therefore, teachers should be prepared and trained for the different modalities. Also, the 4IR could advance the coverage and quality of education and other services available in rural contexts (Ayentimi & Burgess 2019:645). Thus, access can be opened, but this might imply that teachers in all communities must be prepared for constant and perhaps even disruptive change and the use of different modes of learning delivery.

Importantly, Schwab (2016:99) notes that '[t]he Fourth Industrial Revolution may be driving disruption, but the challenges it presents are of our own making' and that '[i]t is thus in our power to address them and enact the changes and policies needed to adapt (and flourish) in our emerging new environment'. Therefore, it is in the hands of those involved in HE to drive and direct developments in this context and through teacher training have an impact on the school environment.

As stated earlier, the concept of lifelong learning is essential in the context of the 4IR. In one sense, it is probably impossible for human beings not to keep on learning, but teachers often fall into what Iredale (2012, 2018) calls 'routinised practices'. In this regard, Iredale (2012) observes that current teacher training in HE is controlled, driven by specific standards and competencies.

In this context, following a self-directed multimodal learning approach could mean that student teachers and teachers acquire the necessary skills to develop themselves in order to counter these practices. However, the context should be conducive to such developmental actions and being motivated to do so is essential. In support of this focus on self-directedness Selvi (2011) notes that:

> [*T*]eachers' lifelong learning skills consist of self-direct learning skills, ability of seeking out and access to knowledge, critical thinking skills, lateral thinking skills, communication skills, interpersonal skills, problem-solving skills, ability of planning projects, ability of evaluating alternatives, ability of working in teams and ability of working collaboratively with their colleagues and students. (p. 66)

Self-directed learning, among other aspects, is acknowledged as being highly relevant for teacher education. However, this chapter specifically looks at preparing education students for self-directed multimodal learning for the 4IR in the South African context, and hence more details about this context should be explored.

Towards self-directed multimodal learning

The relevance of self-directed multimodal learning for the university context is acknowledged by Olivier (2020a) as SDL in HE is realised within a context of multimodal learning where multimodality is relevant in terms of the preferences by individuals, different forms of communication, learning and delivery. The conclusion of Nouri (2019) in this context is as follows:

> [*T*]he way university students make meaning and build knowledge during self-study have changed; that technology make available other semiotic resources for them than the text thus transforming monomodal learning practices into multimodal learning practices. (p. 695)

Therefore, SDL and the multimodal nature of the learning context are increasingly intertwined. In addition, meaning-making is essential to any success in the learning process. If self-direction among student teachers is a goal, then the concept needs to be unpacked and delineated. The widely quoted definition of SDL by Knowles (1975) provides a clear description of this phenomenon:

> [*SDL is*] a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies and evaluating learning outcomes. (p. 18)

This definition emphasises student agency and process that does not imply total autonomy but rather a communal interdependent effort. Furthermore, this definition covers some form of diagnostic reflection, goal setting, resource and strategy selection and evaluation on the side of the individual. The challenge would be to determine how this process can be integrated even more into the teacher education sector, as it should not be assumed that this is not being already done in some contexts. However, the assumption cannot be made that SDL might be lacking in all contexts. However, according to De Beer (2019:129), SDL can be considered 'an issue of social justice, and it is essential to prepare learners for a complex 21st century'. Consequently, the emphasis on SDL for teacher education is warranted.

Education is and will increasingly be multimodal. For Jung (2020:136), the 4IR relates to fairly recent sudden changes in technology and society. Furthermore, Schwab (2016:88) concurs by stating that '[n]ew forms of digital media, which form a core component of the Fourth Industrial Revolution, are

increasingly driving our individual and collective framing of society and community'. Hence, different modes of communication, learning and delivery are evident with the increased use of electronic media within classrooms at all levels.

In the next two sections, some specific aspects relevant to this discussion of self-directed and multimodal learning are explored further in order to contextualise these two phenomena.

Self-directed learning

Central to the concept of SDL is the fact that students take responsibility for their own learning (Bosch et al. 2019) and this ties in with the definition provided in the previous section. This approach contradicts a more traditional view of the teacher being the authoritative person holding knowledge and learners acquiring that from the teacher (Kress & Selander 2012:266). The focus on SDL is part of greater move to a student-centred paradigm in HE (Strydom & Prinsloo 2020). The approach to SDL in this chapter extends further than Smith's (2017) view of it as:

> [*B*]eing about positioning teachers to be key decision makers in their own professional learning, determining the learning that personally matters to them while actively shaping the conditions to most effectively support such learning. (pp. 33–34)

Importantly, Brockett and Hiemstra (2019:34) make the following observation in terms of SDL and the role of others in the process: 'individuals will vary in their readiness for self-direction thereby requiring varying degrees of assistance by facilitators, especially as SDL skills are developing'. Hence as students are on a continuum in terms of their self-directedness within specific contexts, a differentiated approach with adequate teacher and or peer facilitatory support might be necessary. In this regard, Johnson and Johnson (2019) describe SDL as a social endeavour.

Similarly, despite the emphasis on learning being student-centred, Bosch et al. (2019:24) acknowledge the fact that the educator still has a role to play in facilitating the process through which students reach higher levels of self-directedness in their learning. They also propose cooperative learning, problem-based learning and process-oriented learning as appropriate teaching methods to support SDL (Bosch et al. 2019). *Cooperative learning* implies students working together towards a shared learning goal (Johnson & Johnson 2019). Furthermore, 'cooperative learning' can only occur, according to Johnson and Johnson (2019:38) with the inclusion of the following five elements: 'positive interdependence, individual accountability, promotive interaction, appropriate use of social skills and group processing'. The concept of *problem-based learning* can be described as a 'pedagogical approach that enables students to learn while engaging actively with meaningful problems'

(Yew & Goh 2016:75–76). However, according to Ebner et al. (2010) process-oriented learning is achieved only once the student's learning process as a form of knowledge construction takes place. Teacher education should embrace these and other relevant methods towards fostering self-directedness among student teachers.

'Active learning' is also highly relevant within the SDL context, and it involves creation on the part of students. Nouri (2019) proposes that students become actively involved in designing meaning within multimodal contexts and this involves developing relevant multimodal literacies. This aspect relates to what Olivier (2020a) calls *demiurgic learning*, where students are co-creators of knowledge in the classroom. Olivier (2019) identified several SDL requirements and equivalent multiliteracies needed in support of this approach. Further requirements for SDL in this context include problem-solving, collaboration, resource selection, critical thinking, motivation, initiative, self-monitoring, self-management, metacognition, integration of thought and integration of resources (Olivier 2019). Preparing student teachers for SDL therefore involves several literacies. In addition, the multimodal context may also imply certain requirements.

Multimodal learning

Key to multimodal learning is the concept of multimodality. Olivier (2020a) describes these two concepts as follows:

> [*M*]ultimodality refers to the dynamic application of different modes, while multimodal learning refers to individual modal preferences, communicating through different modes, learning and teaching by means of different modes and education taking place through different modes of delivery. (p. 119)

It is imperative to note that the field of multimodality, as regards communicative artefacts, is a diverse and multidisciplinary field (Wildfeuer et al. 2019), and the approach to multimodality in this chapter also draws on this wider scholarship. For Wildfeuer et al. (2019), *multimodality* explores meaning derived from different semiotic modes while considering both the individual nature of modes as well as the way in which they are combined. Teachers and students are constantly busy with such meaning-making activities using different semiotic modes in order for learning and interaction to be successful. Consequently, knowledge about how such modes can be effectively employed should be considered within a multimodal learning approach.

Multimodality plays an imperative role within the 4IR, especially in regards to the interplay and needs of the different levels. As such, relevant aspects of multimodality should be considered from an *individual*, an *interactional*, an *instructional* and an *institutional* perspective. (cf. Olivier 2020a, 2020b). All these relate to learning as communication (Canale 2019) as viewed through

the lens of social semiotics (Bezemer & Kress 2016; Wildfeuer et al. 2019). To clarify, according to Wong (2019), social semiotics as a social theory of meaning as well and communication involves the use of semiotic resources by sign makers for specific social purposes within a social context.

Therefore, there needs to be a clear emphasis on how semiotic resources can be used in teaching settings in the training of BEd students.

The importance of the multimodal nature of the learning context also relates to what is called hybrid or blended approaches to learning. In this regard, Strydom and Prinsloo (2020) state:

> Developing a blended (hybrid) learning environment that makes use of innovative course design to create a flexible learning environment where students can learn in different ways at different times, is critical to ensure that graduates are equipped with the necessary digital literacy skills that they need to succeed in the 21st-century work environment. Therefore, the adoption of a blended learning model where face-to-face [F2F] class time and educational technology-enhanced learning and teaching methods are integrated is strongly encouraged. (pp. 154–155)

This instructional multimodality (Olivier 2020b) is pertinent to the changing educational context in higher and other levels of education. This flexibility also allows for differentiation of learning for students. Through modelling a differentiated approach to education students, they can potentially also adopt such an approach and model it to their own learners in their teaching practice and consequently show sensitivity towards individual multimodality. Hence, universities should reflect a true self-directed multimodal learning nature.

Individual multimodality refers to personal preferences for learning and communication modalities (cf. Olivier 2020a, 2020b). Nouri (2019) also supports the notion of individual multimodality, as according to him, if students can customise their learning according to their modal needs, then education itself might become more inclusive. HE should be responsive to the individual needs of students in order to exploit their most appropriate and effective ways of learning and interaction. Importantly, it should not be assumed that all current students prefer online learning and might need additional support or different options.

Within the milieu of individual multimodality, the varied and changing needs of student teachers must be considered. As the student population is diverse with regard to exposure to different modalities, especially in terms of technology, a differentiated approach is essential in the university context. Some students share characteristics of the so-called demographic cohort Generation Z (or Gen Z for short), while others may have had limited access to technology because of the digital divide. Importantly, the Joint ILO/UNESCO Committee of Experts (2018) also expressed the following concern:

> The inclusion of digital technologies in education should be used with a view to supporting learning and improving quality, and should not create further inequities

> in education. Teachers need to be pedagogically prepared to effectively use technologies through high-quality pre-service and in-service programs. (p. 2)

A differentiated approach would also imply some customisation. In this context, Seemiller and Grace (2019) make the following observation:

> Aside from having the ability, in many cases, to create their own course schedules and select electives of interest to them, Generation Z students want even more customization like being able to engage in college a la carte where they can opt out of the extras of the college experience. (p. 197)

The student population focussed on teacher education can increasingly be associated with Gen Z (Seemiller & Grace 2019). In this regard, Seemiller and Grace (2019:196) state that, '[o]ne misnomer about Generation Z is that their desire to be digitally connected means they solely want online learning'. They add that, as online courses are created instead of courses focussed on in-person learning, such online learning opportunities are more aligned with what older individuals who are already working might prefer in comparison to members of Gen Z who might prefer face-to-face (F2F) interaction (Seemiller & Grace 2019).

Yet, it remains to be seen what the situation will be for the generation after Generation Z. However, within the current educational context it is important to note that preferences vary over time and between individuals. Such inherent variation prompts the need for a multimodal approach, and in the next section self-directed multimodal learning for teacher education is briefly discussed.

Self-directed multimodal learning for teacher education

For Olivier (2020a:120), self-directed multimodal learning involves students 'being self-directed in selecting modes of learning and communication appropriate to an individual'. However, within the teacher training context, multimodality extends further than just accommodating student preferences and mediating communication. As stated, a multimodal learning approach also implies embracing new technologies.

Within the 4IR, new technologies such as virtual reality are highly relevant. Cooper et al. (2019) explored how virtual reality could be used in HE. They observed that '[p]reparing students to effectively navigate, contribute to and participate in virtual environments appears to be an important future set of skills and knowledge' (Cooper et al. 2019:10). The affordances of such technologies in preparing teachers for real-life situations should be explored further.

In order to interpret self-directed multimodal learning for teacher education, specific needs can be identified in terms of the levels (Table 3.1) of multimodality (Olivier 2020a, 2020b).

TABLE 3.1: Operationalisation of the levels of multimodality for teacher education.

Level of multimodality	Operationalisation
Individual multimodality	• Student modal preferences need to be identified through diagnostic and learning analytics. • Learning environments and resources should be flexible to address different students' diverse needs; consequently, data-driven adaptive learning methods would be relevant.
Interactional multimodality	• Communication in class and for learning should be conducted through different mediums as appropriate. • Learning as communication should be embraced in the classroom. • Teacher training should focus on not only verbal communication but also effective nonverbal communication, F2F, but also online. • Lingual resources should inform meaning-making in the classroom brought in by students and should be constructed collaboratively.
Instructional multimodality	• Technology should be blended with F2F interactions in support of pedagogical goals. • Multimodal assessments – assignments that are not only text-based and may include graphical, animation, video, virtual reality and other multimedia content – should be used. • Instruction should be structured to allow students to select their own technologies and resources for learning as appropriate. • Learning should involve strategies such as cooperative learning, problem-based learning and process-oriented learning to foster SDL.
Institutional multimodality	• Flexible learning delivery over distance, contact or through a hybrid approach can be adopted. • Restrictions in terms of distance and the actual time of learning need to be reconsidered.

Key: SDL, self-directed learning.

Within the context of the 4IR students' needs, dispositions and contexts are highly significant. Schwab (2016) underscores the importance of four specific intelligences in the context of the 4IR, namely contextual, emotional, inspired and physical intelligences. The importance of context in SDL is further highlighted by De Beer (2019). This ties in with Schwab's emphasis on contextual intelligence, which implies understanding the affordances of networks that are diverse and able and willing to anticipate evolving trends and make appropriate connections (Schwab 2016). Furthermore, Schwab (2016:101) believes that 'emotional intelligence is the vital foundation for skills critical to succeed in the era of the Fourth Industrial Revolution, namely self-awareness, self-regulation, motivation, empathy and social skills'. These affective variables also support self-directedness, so preparing students and teachers for the 4IR is not just about integrating technology and training for innovative technologies but also about *establishing human relationships*. This is especially relevant in a context where collaboration between people is appropriate for the learning situation.

Collaborative learning is closely associated with SDL. However, Seemiller and Grace (2019:205) reported that not all Gen Z students prefer learning in groups, as they found that 'only 49 percent of middle and high school Gen Z learners prefer learning that involves small-group work' and that a similar number of students did not prefer interpersonal learning and opted for intrapersonal learning. This concept ties in with a sense of community as well as what Schwab (2016) describes as *inspired intelligence*. According to Schwab (2016):

> [/]f technology is one of the possible reasons why we are moving towards a me-centred society, it is an absolute necessity that we rebalance this trend towards a focus on the self with a pervasive sense of common purpose. (p. 101)

For Schwab (2016:102), physical intelligence 'involves supporting and nourishing personal health and well-being' and '[u]nderstanding and grasping new ways of keeping our physical bodies in harmony with our mind, our emotions and the world at large is incredibly important'. In this regard, the challenge will be to prepare student teachers to understand and manage this balance in their own lives.

The importance of fostering SDL within a multimodal environment is also highlighted through the following statement by Reaves (2019):

> Teaching skills becomes more important than transferring knowledge, because the global library is already in the cloud, constantly updated with the latest research and developments and instantly available to the individual. It is less important to transfer that library to memory than to practice navigating the cloud, finding the right resources and applying knowledge to the problem at hand. The emphasis is on doing-to-learn rather than learning-to-do. (p. 7)

Consequently, the way knowledge is stored and accessed is changing and has already changed dramatically and the focus should be on skills accessing the knowledge, selecting and critically engaging with knowledge as well as ethical conduct throughout the whole process. Central to this approach is also the concept of fostering self-directedness among students not only in obtaining resources, as mentioned above, but also creating knowledge and taking charge for their own lifelong learning process. In the next section, some recommendations towards this goal within teacher education are presented further.

Implications

In light of the discussed context, several recommendations are made for preparing education students for self-directed multimodal learning within the wider context of the 4IR.

It is essential for student teachers to be active creators of knowledge. They should have adequate demiurgic access to be able to create and not just consume within the teacher education context. Olivier (2020a:123–124)

describes *demiurgic access* as 'the type of access for students that would make the circumstances optimal for them to be successful co-creators of knowledge and contributors to content'. Furthermore, Nouri (2019:695) is of the opinion that the way in which students construct and consume learning material tends to be multimodal. Hence, both the lecturer and student-teacher need to be empowered to effectively use resources on the levels of interactional and instructional multimodality.

In agreement with the aforementioned, learning in general should be student-centred (cf. Gleason 2018), and 'educators should give more freedom to students and trust them to fulfil certain responsibilities' (Bosch et al. 2019:35). Hence, within the context of learning as communication, 're-valuing of the agency of both the "sender", in traditional terms, and the "receiver", now seen as an interpreter of the message taken as a prompt' (Kress & Selander 2012:266) is needed. Within a multimodal learning context, this educational communication at all levels of education should not just be two-way communication but also in multiple directions as learners themselves collaboratively contribute to meaning-making in the classroom.

A critical approach to knowledge should be taken by lecturers, as the fusion of different technologies does not only lead to the automation of production but knowledge as well (Gleason 2018). In this regard, Gleason (2018:7) also notes that '[m]etacognition is important because it is linked to information literacy, an essential element of intelligence in the post-truth era'. In addition, metacognition has also been explored in SDL research (Van Zyl & Mentz 2019), but further research is needed in the South African context where students are scaffolded in strategies supportive of metacognition in their resource-selection attempts.

The learning experience should be authentic (Gleason 2018) and relate to real-world problems. Learning should be contextualised (De Beer 2019) and be appropriate for students and their specific milieu. Teachers must be prepared for diverse learners and contexts. In this regard, the Joint ILO/UNESCO Committee of Experts (2018:2) suggested that teacher training 'should include preparation to work effectively with diverse learners, especially in areas related to digital technologies, socio-emotional development and demands from the world of work and society' (Experts 2018:2) and that teaching should be focussed on inclusivity and being able to reflect actual societal diversity. In this regard, the need for work-integrated learning or practical experience is essential, but scaffolding towards that goal by means of virtual reality and simulated classes should also become mainstream.

Learning should be portable, flexible and, hence, mobile. In this regard, Nouri (2019) found that his research portrays university students of today as:

> [*L*]earners that in a mobile and flexible way use the affordances of different technologies, particularly portable mobile technologies, in order to construct knowledge through different semiotic modes when they are to create meaning out of course related content and activities during self-studies. (p. 696)

Within the wider multimodal learning context, teachers should be able to use multimodal forms of representation in content. This is important because of the fact that changes in terms of communication, technology and even culture have had an impact on how scientific knowledge is generated and transferred (Nielsen et al. 2019). For Nielsen et al., the concept of digital explanation is central to a multimodal learning approach. Furthermore, it is evident that '[c]onstructing a digital explanation is an opportunity to build knowledge through translating science content multimodally, but such tasks impose significant technical and conceptual demands on the creator' (Nielsen et al. 2019:273). This aspect ties in with the need for increased multimodal assessments.

Assessment should also be considered as an aspect that needs to adapt to the new context. In this regard, multimodal assessments can be useful as such assessments – even at the summative level – are not just text-based but also inclusive of using sound, graphical content, animation, video and any other multimedia content. In this regard, Nouri (2019:697) believes that we should move away from the domination of monomodal assessment practices. In addition, the volume of assessment should be evaluated. Seemiller and Grace (2019:191–192) state – in reference to standardised testing in the USA – that many school learners 'have spent time that was previously allocated to arts and wellness instead on test preparation and test taking'. In addition, assessments will have to become more multimodal to reflect realities outside of the classroom.

The skills taught at school should be relevant. Gleason (2018) observes that '[e]veryone is now responsible for lifelong learning and upskilling', and consequently, skills are essential for success rather than content that tends to be more changeable. In addition, the 4IR would also require specific skills from students. Seemiller and Grace (2019) note:

> [*A*]s the educational settings populated by Generation Z students continue to become digitised, it is critical that they learn the skills associated with effectively utilizing tech tools and platforms as well as navigating the online world. (p. 191)

Seemiller and Grace (2019:191) go so far as to claim that 'coding is the new cursive, and that teaching kids to code may be far more useful than spending time teaching obsolete cursive writing'. Consequently, curricula should be flexible enough to include additional skills as they become relevant and student teachers need to be able to adapt to such changes in needs. Timmis and Muhuro (2019:263) urge that universities 'develop a more critical

awareness of the effects of a technocratic culture and involve students themselves in the process of change'. The decolonised digital education they propose would require acknowledging and supporting a number of multiliteracies required for university students.

To facilitate effective functioning in multimodal contexts, it will be necessary for student teachers to be prepared and supported in using technology at the university level. Timmis and Muhuro (2019) found that:

> [*D*]espite the supports in place and their own agency and improvisations, students frequently felt positioned in deficit and alienated by the technocracy they encountered and it was left to them to decode the digital education systems and practice for themselves. (p. 263)

Consequently, an infusion of technologies within a learning context should also include sufficient training and support in order for both lecturers and student-teachers to make effective use of such technologies. This starts with basic digital literacies but also extends to learning management systems and different apps and platforms included in the learning process.

The affective role lecturers play should not be ignored. According to Seemiller and Grace (2019), Gen Z students have a preference for teachers who are excited about teaching their content; such students excel if teachers are committed to the students' personal and academic progress. Therefore, teacher education should build on existing good practices in preparing teachers to be caring educators, but also consider how this would be realised in an online context.

To support lifelong learning, incentives should be provided for informal learning done by teachers in addition to formal continuing professional development (CPD). However, in regard to professional development, Iredale (2012:61) remarks that such professional development must be relevant and meaningful, but also broad and flexible enough for teachers, in order to change their practices. Hence, even formal CPD should embrace multimodal learning and foster SDL. Research by Wittmann and Olivier (2019) shows how SDL can be fostered in German language teachers in South Africa. However, Taylor (2019:272) noted the differences in needs for initial teacher training versus CPD, as '[a]ll CPD must take account of the generally very low levels of disciplinary knowledge held by the teachers they work with, and high variation in knowledge across the population'.

Despite Smith's (2017:43) focus on in-service training and her narrow view of SDL, the following identified aspects of teacher SDL are of value for teacher education in general:

- building a sense of professional identity
- reflecting on professional reasoning to clarify personal professional principles of practice

- identifying tensions between principles of practice and action
- realigning action with professional thinking
- sharing new professional knowledge.

In light of these aspects, student-teachers and higher education institutions responsible for teacher education can attempt to address some of the needs of the 4IR.

Conclusion

The ever-changing education context will require changes as to how teacher education and training takes place. The 4IR will likely have an influence on the wider education sector. Yet, it is not yet clear what effect changes in the physical, digital and biological spheres (cf. Schwab 2016) will have on teacher education. Nevertheless, as suggested in this chapter, students who embrace multimodality and who are self-directed could be able to adapt to neoteric circumstances.

Teacher education should not be confined to set competences and, in this regard, Chisholm (2019) makes the following important remark:

> Although competences are not a bad thing, the purpose of teacher education should transcend this goal and seek to open teachers to new ways of confronting the world. As such, it should not just aim to equip them with specific knowledges, skills and competences, and try to socialise them to fit into a changing world or specific type of society, however well-conceived, but should enable them to think beyond it. (p. 175)

Lecturers and students must prepare pre-service teachers to handle and embrace change to ensure successful teacher education and training. Furthermore, the direction of teacher education is in the hands of these lecturers and students; they will have to determine how the future teacher education sector will react towards and fit within the 4IR which requires thinking beyond what is currently possible within the confines of HEIs.

This chapter provided an overview of relevant issues from the scholarship on 4IR, SDL and multimodal learning towards preparing education students for self-directed multimodal learning for this revolution. The complex context of teacher education was discussed, specifically focussing on SDL in the context of the 4IR. Finally, recommendations were made for preparing education students for self-directed multimodal learning for the 4IR. But at this point, there are many unknowns, and teacher education should be prepared for constant (hopefully positive) disruption.

Chapter 4

Transforming teacher education in the context of the 4IR through the Internet of Things and social presence

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Abstract

This qualitative literature study focusses on two components of the 4IR: the IoT and social presence in the transformation of teacher education and training. Hence, the study's purpose explores the role played by the two 4IR components in transforming teacher education as part of HE. The two components form a critical platform through which the transformation of communication and social interaction in HE becomes possible. The study adopted a qualitative systematic

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literature review design using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Therefore, the data used consisted of 20 systematically selected articles from Google Scholar on the IoT and social presence in teacher education and HE published in the 2010–2019 decade. Data were analysed using thematic content analysis techniques that bore three major themes. The findings provide insights on how teacher education transforms through integrating the IoT in teaching and learning while negotiating the tensions to ensure a meaningful social presence in the online classrooms. The transformation of teacher education points to the need to reimagine instructional modes and work-integrated learning through frameworks based on the IoT integration that ensures meaningful social presence. The study also highlights three important theoretical frameworks that can be used to understand teaching and learning in online classrooms and virtual environments to be the community of inquiry (CoI), the IoT and Social Internet of Things (SIoT). Recommendations for further studies are also made.

Introduction

The perfect storm of Fourth Industrial Revolution (4IR) technologies is paving the way for transformative changes (McGinnis 2018) in educational institutions. For some time, higher institutions have been on the verge of a technological transformation that would drastically change the way they operate, deliver content and relate to one another (Schwab 2016). These institutions are expected to participate greatly in reshaping the future of the 21st-century students by being the test agents for educational transformation. It is supposed that the new emerging 4IR technologies that are coming up at an unprecedented, whirlwind pace (McGinnis 2018), would help students to achieve improved holistic educational learning conditions and cognitive wellness. The 4IR's transformation of HE teaching and learning practices has brought about a shift in the wealth of knowledge (Schwab 2016), and enabled increased ease in knowledge and information sharing across the globe. The relevance and need for a rapid transformation through the imminent technological revolution in HE became more apparent in 2020, as more than 90% of the world's student population was forced to be out of school because of the COVID-19 pandemic (Commonwealth of Learning 2020). Online and distance learning became the only means of keeping the doors of the institutions open during the time that social distancing was mandatory (Commonwealth of Learning 2020). South African HEIs were among the institutions that adopted online and distance modes of instruction during the COVID-19 pandemic. The adoption of online and distance learning came on a backdrop where South Africa was already using a variety of blended learning approaches that incorporated the use of LMSs and other educational technologies (Kinuthia & Dagada 2008). However, the blended learning approaches have been constrained by a number of challenges that include lack of resources (Kinuthia & Dagada 2008).

Because of the many challenges that stand in the way of applying the IoT affordances in Sub-Saharan HE, Atayero, Oluwatobi and Alege (2016) point out that the region is joining the IoT component of the 4IR at a developmental stage. The sub-Saharan region trails behind all the other regions in the world with Europe placed top on the list in terms of the adoption of the IoT in HE (Atayero et al. 2016). Amongst the disparities that result from the differential adoptions of the IoT in different countries is an observed digital exclusion of marginalised populations and growing digital divides (Khalid & Pedersen 2016). It is against this background of the integration of the IoT in HE that Xing, Marwala and Marwala (2018) recommend that South Africa should use approaches that allow for quick adoption and fast adaptation.

Therefore, all the stakeholders in HEIs must respond to the 4IR set of skills, including the IoT applications by preparing students as a future workforce that understands interconnected systems when engaging in problem-solving in the future (Schwab 2016). To achieve this outcome, HEIs should rethink their traditional curricula, such as the synchronous delivery of content to new perspectives of possible asynchronous modes of instruction. However, substantial transformations need to take place with a focus on allowing students to experience the IoT digital devices and platforms in order to participate in an online environment that provides a sense of social presence. Digital technologies that the 4IR has brought, are worthy to be admired however, the success of using them would be determined by how content is delivered by teacher educators and whether they provide maximum benefits to students.

Teachers' education, the IoT and social presence competencies are crucial in ensuring the success of preparing their students to be technologically informed citizenry. They should be mindful of the opportunities provided by the 4IR in terms of accessing and navigating systems, the ability to synthesise data and change them into manageable and understandable information and various means of Internet communications. The use of the IoT and social presence provide enormous opportunities for students from diverse backgrounds (Penprase 2018), as they engage in a flexible and more efficient online environment where interacting objects both physical and virtual are used as a medium of teaching and learning (Abbasy & Quesada 2017). Teacher educators cannot ignore the rapid advancements of technologies in HEIs as these drastically change the way they conduct classroom practice (Bagheri & Movahed 2016). In this study, we reflect on the transformation of pre-service teacher preparation as part of HE in the context of the 4IR through the concepts of the IoT and social presence.

The Internet of Things

Interactive and collaborative environments among people and machines are a reality in the 21st century. The advent of the IoT has transformed communications among humans, between humans and machines and among machines

(Ramlowat & Pattanayak 2019). Teacher education and training in HEIs are experiencing the fast-evolving digital era of the IoT, and so should HEIs take the lead in using and developing IoT-enabled teaching and learning. Motala and Padayachee (2018) define the IoT as a technology that allows through sensors the interconnection of Internet capable devices that increase communication and openness of information, while these interactions enhance online learning in HE.

Mukhopadhyay and Suryadevara (2014) describe the IoT as the embedded digital devices with Internet connectivity allowing interaction with each other, services and people globally. Deters and Samaniego (2016) share the same sentiment, as they argue that the IoT is basically the idea of connecting physical devices with the Internet which in HE results in new and richer teaching and learning interactions. In addition, Xia et al. (2012) add that the networked IoT interconnections are often equipped with abundant intelligence. This abundant intelligence, according to them, is the incorporation of physical objects that can be used to manage data through collection and sharing. The objects in the interactive collaborative environment are monitored and controlled remotely, giving rise to enormous new opportunities for better interaction between physical and digital worlds.

For Abbasy and Quesada (2017), the IoT facilitates interaction between the real and virtual objects and its development and maturity would influence teaching and learning, including HE. Studies have been conducted on the integration of the IoT in education. Aldowah et al. (2017) examined the potential of the IoT in HE, including its benefits and challenges. They argued that the use of IoT systems can alleviate longstanding challenges experienced in attempts to engage students meaningfully and motivate them during learning although they acknowledge that more research is needed in order to understand the use of the technology better.

However, there are some studies that have been conducted in the context of HE on the influence of the IoT in teaching and learning. One study was conducted by Banica, Burtescu and Enescu (2017), where the authors sought to investigate the importance of introducing the IoT in HE. The results showed that the IoT platforms with real-time use of cloud computing services are regarded as the optimal technical solution for teaching and learning activities (Banica et al. 2017). What the authors seem to imply is that IoT enables the creation of Smart Universities because they improve systems efficiency for teaching and learning and other support services.

Another study by Abbasy and Quesada (2017) focussed on the predictable impact of the IoT in HE. Their study was based on the projected information that the IoT can be used to develop embedded applications that can gather information on students and highlight their learning needs. The results of the study confirmed that IoT-enabled instructors to learn about factors that

influenced the teaching and learning processes. Collaborative learning, conducting research and interactivity are some factors that can be managed in the teaching and learning process. (Abbasy & Quesada 2017). Similarly, Hernandez et al. (2018) devised a diagnostic observation tool to study the use of the IoT in HEIs of Barranquilla and its metropolitan area. The results of the study provided a diagnosis of the state and role of IoT used in the institutions and the challenges encountered. The study made a contribution in raising awareness on the important role of IoT in formal education.

Hernandez et al. (2018) and Zhamanov et al. (2017) pointed out the four pillars of the IoT: people, process, data and things. According to Hernandez et al. (2018), these IoT pillars have created an interest in HEIs to have education systems that equip new generations of digital natives who are functional and proficient in the emerging technologies' environments enabled by the IoT and in interacting with the information that is collected and shared. Zhamanov et al. (2017) in addition declared that the IoT pillars simplify and make faster billions of operations worldwide to be realised. Each pillar amplifies the capabilities of the other three and the intersection of all convey the true power of the IoT in teaching and learning (Hernandez et al. 2018). The most common application of the IoT in HE is the facilitation of e-learning that provides students and lecturers with the opportunity to work together in real time (Abbasy & Quesada 2017).

Motala and Padayachee (2018) sought to understand the perceived benefits, as well as the technological and environmental barriers of adopting the IoT approach in HE. The findings emphasise the acknowledgement of IoT benefits, namely remote flexible connection, increased communication and creativity when learning. The findings of the study further revealed that the IoT approach does have some technological barriers in terms of Internet capability and network security, as well as challenges such as data privacy and protection. In terms of how the IoT is integrated in higher education institutions, Zhamanov et al. (2017) point out that the IoT has strengthened ICT in the current interactive online learning environments by providing more flexibility and reachability from anywhere to anyone globally. Accessibility and collaboration among humans and various objects through the use of Internet daily provide participants with unlimited information from anywhere, anytime, which is a new horizon of sharing information and development already in place in higher education (Sagenmüller 2018).

Zhamanov et al. (2017) observe that currently, digital devices connected to the Internet are mostly personal computers, laptops, tablets, TVs and smartphones, and they foresee more autonomous devices that would be connected to the Internet. Mukhopadhyay and Suryadevara (2014) share the same sentiments as they highlight that the level of connectivity would increase reliability, sustainability and efficiency as the results of improved access to information. The use of IoT enables the management and handling of huge

amounts of data through applications such as cloud computing and radio frequency identification (Sagenmüller 2018).

Experimenting with the IoT in higher education institutions has shown that collaborative learning environments that provide more interactive learning experiences, improved operational efficiency as students enjoy real-time and creditable performance are enhanced (Aldowah et al. 2017). The integration of the IoT has shifted from being about technologically savvy, to being about skills inherent to 21st-century citizens, such as the sharing of knowledge and information, communicating efficiently, building learning community of practices and creating a culture of professionalism in education institutions (Aldowah et al. 2017).

There is great potential in processes offered by the IoT in teacher education as part of higher education and these largely remain as opportunities that must be identified and developed (Hernandez et al. 2018). These processes, if selectively integrated in teaching and learning, would undoubtedly improve the quality of education in general. Higher education institutions are dramatically transformed by the integration of the IoT, as it enhances the delivery of content in many disciplines and levels. If the IoT is appropriately adopted, there will be an assurance of its use to improve teaching and learning by all stakeholders (Aldowah et al. 2017). The IoT empowers universities and enables them to become leading educational institutions. Based on the deliberation above, we can posit that embracing the IoT in HEIs would bring a tremendous fundamental shift that results in the transformation in teaching and learning.

Social presence

Parting from the constructivist idea that learning is a social process that results from the interaction of people as they cooperate, collaborate and co-construct knowledge, social presence was selected as one of the lenses to study the transformation of teacher education in the 4IR environment. With the increased use of new technologies in the 4IR era, there is also a growing interest on how social presence manifests in online environments. According to Çakmak, Ayça and Adnan (2014), social presence is related to the feeling of the other peoples' presence in a social context and a feeling of sharing information with other people in the communication process. For Annand (2011), social presence is useful as a framework to interpret collaborative behaviours and interactions in online classrooms. The framework can be used to explain students' participation patterns and their ability to learn in online classrooms. In this study, we posit that both teacher educators and pre-service teachers should learn the important skills that would enable them to work in a collaborative virtual learning environment (VLE). Teacher educators should be able to monitor shared thoughts so that some students would not dominate the discussions, thereby

cultivating a sense of belonging for all in the group. In defining social presence, Garrison, Anderson and Archer (2000) give an indication of what constitutes effective interaction that is underpinned by important values such as a sense community, trust, honesty and commitment. For them, mutual interaction helps in shaping students' learning activities and the development of their relationship within a VLE. However, Cui, Lockee and Meng (2012) maintain that social presence varies among different digital technologies used in an online learning environment and thus a choice of one technology may give rise to a particular nature of communication and interaction. For example, the use of synchronous online strategies may give different social presence experiences from when asynchronous strategies are used.

Social presence in online classrooms is defined by Kreijns et al. (2011) as a sense of being together in one community or group, similar to what students would feel if they were in physical and face-to-face learning environments. Consequently, in online classrooms students also engage in social processes that define group dynamics and identity. Consequently, according to Kim (2011), social presence is a valuable framework for understanding psychological and emotional relationships among diverse distance-learning students. In line with the definitions echoed in earlier studies, the transformation of education in higher education rests on guiding and capturing other users' attention instead of participating in a VLE merely for the sake of participating. Deliberate efforts to enhance social presence experiences in online classroom settings are recommended for this will benefit HE students (Annand 2011; Cui et al. 2012). Oztok and Brett (2011) note that the idea of maintaining an effective social presence has long been proclaimed as a good practice in VLEs for it improves the perception of learning in students. Learning facilitators play an important role to make sure interactions in groups function well. The learning facilitators' duty, among others in a collaborative learning environment, is to ensure that students participate equally without other students dominating the discussions in the VLE.

Group-based learning is recommended by Annand (2011) as one way to enhance social presence in virtual classrooms. However, the study by Oztok and Brett (2011) concludes that students may interact and collaborate in online learning environments without feeling that they are part of the group. The finding opens up possibilities of further research on how to enhance the sense of belonging and perception of group formations in VLE. Some studies focussed on developing data-collection tools that can be used to investigate aspects of social presence in VLE. Kreijns et al. (2011) and Çakmak et al. (2014) developed and validated a data-collection instrument to measure variables pertaining to the perceived social presence in online classrooms for groups of students participating in collaborative learning. Social presence is one of the three important variables identified by the theory of CoI (Garrison et al. 2000) in the online learning environment and should receive adequate acknowledgement

and be adequately embedded in the VLE in education (Cui et al. 2012). Ensuring a social presence in which students feel like they are socially connected to one another is important because online learning can be very lonely according to Kaufmann and Vallade (2020). Developing a functional social presence as a premise for learning aligns with longstanding learning theories such as constructivism. Learning is a social process that results from interactions between instructors and students and among students (Pritchard & Woollard 2013). The course designers and instructors for VLE have to direct the social process that facilitates learning in ways that result in an effective and efficient social presence. When planning for social presence in online classrooms, Cui et al. (2012) propose that instructors and designers should have in mind the level of social presence required, make available the required resources, prepare instructors and respond to the students' characteristics. For example, learning materials should match students' needs while the instructor–student interactions should be timely and focussed on sharing, collaboration and co-construction of knowledge. Ignoring the social process may result in minimal participation and limited learning in VLE.

Studies show that a robust and effective social presence brings about perceived learning satisfaction in students in VLE (Kožuh et al. 2015). Instructors and designers should choose online tools that allow students to communicate, share information and engage in the co-construction of knowledge. The perceived learning satisfaction rests on data or information students share and the motives students display, revealed by how they interact with peers in a VLE. There are some practice recommendations for online facilitators and instructors include conducting a pre-week orientation to help students get ready to participate in VLE before learning gains momentum. In most instances, students come from diversified backgrounds and may have a fear of the unknown when participating in VLE. The facilitator's responsibility is to give students an opportunity to familiarise themselves with the VLE and the course content for them to be ready to participate in class discussions. For example, to get acquainted, they can start by introducing themselves to other students, sharing anything interesting with their classmates or sharing ideas and perceptions about social presence. This informal conversation would make them feel comfortable and encourage them to maintain a social presence in online environments. Annand (2011) argued that the most important characteristic of social presence experienced in HE is the presence of an instructor and other students as participants, particularly at the informal introductory conversations. This initial social presence by the instructor is worth experiencing to alleviate frustrations that may be encountered. The inadequate social presence in VLE is one of the challenges to learning, subsequent student failures and dropouts and a source of frustration for both instructors and students (Reio & Crim 2006) in (Cui et al. 2012).

From a teaching and learning perspective, social presence increases the effectiveness of online instructional modes both in synchronous and

asynchronous environments. One of the outcomes of social presence is flexibility in how students interact in the e-learning environment. Students express and share their thoughts in different ways, including typing into the chat box to ask a question or provide a response and raising a virtual hand for a chance to participate. Flexible online learning environments encourage students to participate freely and share their thoughts more easily (Çakmak et al. 2014).

The careful selection of digital technologies for social presence amplifies and enhances students' learning experiences. Thus, technology selection and methods of delivering content play an essential role in e-learning. An instructor's responsibility is to analyse students' technological knowledge and choose the most suitable digital devices for online communication that help build a robust social presence in online classrooms (Cui et al. 2012). For this reason in this study, we used a combination of social presence and IoT as lenses to explore how teacher education is set to transform in the context of 4IR. Social presence in online classrooms is enabled by IoT technologies inherent to 4IR. Social presence manifests through communication and interaction among people to facilitate learning, but this would not be possible without the IoT tools used to connect people virtually. Some applications that connect people virtually include Web 2.0 tools, including social media (Cui et al. 2012). Despite the immense possibilities presented by the social network, Kožuh et al. (2015) notice that the interactions should be guided to benefit the students instead of harming them because sometimes intimate and personal information is shared.

Method

The study adopted a qualitative systematic literature review design using PRISMA by Moher et al. (2009), following the four steps of identification, screening, eligibility and inclusion. This method of systematic literature review was preferred because it improves how systematic analyses are conducted in terms of ensuring the quality measures of transparency and how the analysis should be reported (Liberati et al. 2009). PRISMA was developed to reduce some of reliability and validity issues that are associated with poor reporting of systematic reviews and lack of detailed steps of how the studies would have been conducted. Purposively selecting the decade 2010–2019 from the Google Scholar database, the keywords *Internet of Things*, *Social Presence*, *Internet of Things in Higher Education*, *Internet of Things* + *Social Presence*, *Internet of Things* + *Pre-service Teacher Preparation* and *Social Presence* + *Pre-service Teacher* were entered into the query and 120‘ studies were identified. The 120 studies were subjected to screening first, by removing 16 duplicates and second by reading the abstracts resulting in the exclusion of 64 articles. To determine the eligibility, the 40 remaining articles were read in full and at the end 20 studies were included in the meta-analysis. The exclusion

criteria included studies that were not located in HE and used frameworks other than IoT and/or social presence. In order to start the thematic content analysis process, the 20 articles were read to determine the purpose of the study, the theoretical frameworks used to anchor the studies, the study methods used and the findings of the studies. The next step was to conduct a thematic content analysis of each article's summaries. The description of the 20 articles is presented in Table 4.1.

The 20 articles were found in 16 journals which focussed on a variety of topics that included computers, education, HE, the Internet, technology education and some that were multidisciplinary. However, the two most popular journals that contributed three studies each to the sample were the *Internet and Higher Education* with articles from Scott et al. (2016), Borup et al. (2012) and Lowenthal (2010) and *Computers and Education* with articles from Kim et al. (2011), Ke (2010) and Yang (2017). The sample of articles covered a number of related topics, including a focus to study the teaching, social and cognitive presence in online classrooms (Borup et al. 2012; Ke 2010; Kim et al. 2011; Lowenthal 2010). The other topic covered by some articles was social networks utilisation as pedagogies in the online classrooms (Atzori et al. 2012; Krutka et al. 2017; Scott et al. 2010; Wang et al. 2016). There are some articles that covered topics on learning interactions and effectiveness in online classrooms (Chang et al. 2019a; Graziano 2017; Hajibayova 2017; Kortuem et al. 2013; Saadatmand et al. 2017; Szeto & Cheng 2016). Four of the articles focussed on tuition of student-teacher in online classroom (Best & MacGregor 2017; Graziano 2017; Waters & Russell 2016; Yang 2017) with Waters and Russell (2016) specifically focussing on the possibility of placing pre-service teachers in virtual environments for teaching practice. Mershad and Wakim (2018) highlighted the importance of LMS in HE and how these are enhanced by efficient IoT systems. Three theoretical or conceptual frameworks were observed to have been used to undergird the sampled articles. These frameworks were the CoI, the IoT and the Social Internet of Things (SIoT). Most of the studies in the sample were anchored in the theory of CoI framework by Garrison et al. (2000) which guided the understanding of the social, teaching and teaching presence. These studies include those by Ke (2010), Saadatmand et al. (2017), Chang et al. (2019a), Armellini and De Stefani (2016), Szeto and Cheng (2016), Kim et al. (2011), Wang et al. (2016), Borup et al. (2012), Lowenthal (2010), Hajibayova (2017) and Yang (2017). The concept of the IoT was explicitly or implicitly used as a framework in all the articles that were part of the sample. The use of social media tools such as WeChat (Wang et al. 2016) for teaching and learning resulted in the use of the SoIT paradigm to understand the findings made in some studies (Atzori et al. 2012; Kurtuka et al. 2017).

The thematic content analysis resulted in the formulation of three themes that would best describe the insights in the transformation of teacher

TABLE 4.1: Description of the sample of articles.

Authors	Journal	Purpose of study	Authors	Journal	Purpose of study
Chang, Lin and Chen (2019a)	*Computers and Human Behaviour*	Explored how cognitive styles influence students' attention levels and learning effectiveness in MOOCs	Mershad and Wakim (2018)	*Journal of Education and Learning*	The study provides a framework for future LMS enhanced by the IoT capabilities
Chang, Lin and Chen (2019b)	*Open Praxis*	Investigating the cognitive, social and teaching presence in MOOCs	Saadatmand et al. (2017)	*European Journal of Open, Distance and e-learning*	Examined learner interaction in open online course using CoI
Armellini and De Stefani (2016)	*British Journal of Educational Technology*	Established the role of cognitive, social and teaching presence of English language teachers in a professional development course in blended learning settings using the CoI framework	Ke (2010)	*Computer and Education*	Used the CoI framework to examine the online teaching, social and cognitive presence of adult students
Scott, Sorokti and Merrell (2016)	*Internet and Higher Education*	Higher education students' use of an enterprise social network in CoI framework	Atzori et al. (2012)	*Computer Networks*	Explored the integration of social networks and the IoT
Kim, Kwon and Cho (2011)	*Computers and Education*	Investigated the factors that influence distance higher education by comparing demographics, social presence and learning outcomes	Szeto and Cheng (2016)	*Interactive Learning Environments*	Explored the social presence experiences and its effects on interactions in synchronous face-to-face and online learning
Krutka, Nowell and Mcmahon-Whitlock (2017)	*International Journal of Technology and Teacher Education*	The study describes the successes and challenges of using social media pedagogy	Kortuem et al. (2013)	*Computer*	Explored the redesign of an open university to put the IoT at the centre of the students' experiences
Wang et al. (2016)	*Australasian Journal of Technology Education*	Explored the affordances of the social media tool WeChat to enhance social presence and cognitive presence	Graziano (2017)	*TechTrends*	Explored the benefits and challenges of flipped classrooms and their impact on learning using pre-service teachers' experiences
Borup, West and Graham (2012)	*Internet and Higher Education*	Explored the use of asynchronous videos to improve social presence based on the CoI framework	Waters and Russell (2016)	*Research in Social Sciences and Technology*	Explored the experiences of pre-service teachers on a virtual teaching practice placement as part of a preparation to work in virtual schools
Best and MacGregor (2017)	*International Journal of Technology and Design Education*	Describes the transition of a BEd Design and Technology course from physical to online classrooms	Yang (2017)	*Computers and Education*	Used the CoI to explore effective feedback practices for pre-service teachers during online learning
Lowenthal (2010)	*Internet and Higher Education*	Examined the use of digital storytelling in order to establish the instructors' social presence in an online classroom using the CoI framework	Hajibayova (2017)	*Cataloguing and Classification Quarterly*	Used CoI to explore students' perceptions of the efficacy of online learning experiences

CoI, community of inquiry; IoT, Internet of Things; LMSs, learning management systems.

education in the context of the 4IR based on the concepts of the IoT and social presence based on the sample of articles. The three themes are (1) IoT tools to facilitate teaching and learning in HE, (2) strategies to ensure social presence in online courses, and (3) transforming teacher education through the IoT and social presence as discussed further.

Internet of Things tools to facilitate teaching and learning in higher education

The IoT enables the use of a number of technologies thereby diversifying the modes of teaching and learning in HE. F2F classroom practices are now complemented by different forms of online teaching and learning. One of the forms of the IoT-enabled teaching and learning practice is the massive online open courses (MOOCs) that offer distance education opportunities for students from different parts of the world. Chang et al. (2019a) point out that institutions of higher learning are increasingly embracing the use of MOOCs to reach out to more students all over the world. Reporting on a MOOCs study that involved 2830 students from 90 countries, Chang et al. (2019b) state the completion rate of the course was 53%. An observation was made in which female and actively participating students were more likely to complete the MOOCs courses. In HE, Mershad and Wakim (2018) observe that the use of LMS is a major breakthrough in the adoption of online learning. Examples of the LMS used in South Africa are BlackBoard, Moodle and Sakai, among others. The IoT expands the range of educational technology tools that can be used for learning and teaching on LMS. These IoT-enabled tools as proposed by Mershad and Wakim (2018) include:

- LMS-enabled experimentation whereby students' access and control laboratory machines and equipment remotely
- LMS-enabled virtual reality experiences such as simulations and virtual tours
- facilitation of remote lectures
- data sharing of real-life projects and experiments
- facilitation of student assessment
- student access to classroom applications such as digital textbooks, videos, wikis and texts
- improved security by granting secure access to teaching and learning materials to users from different locations and
- classroom monitoring for aspects such as engaged learning, participation and attendance.

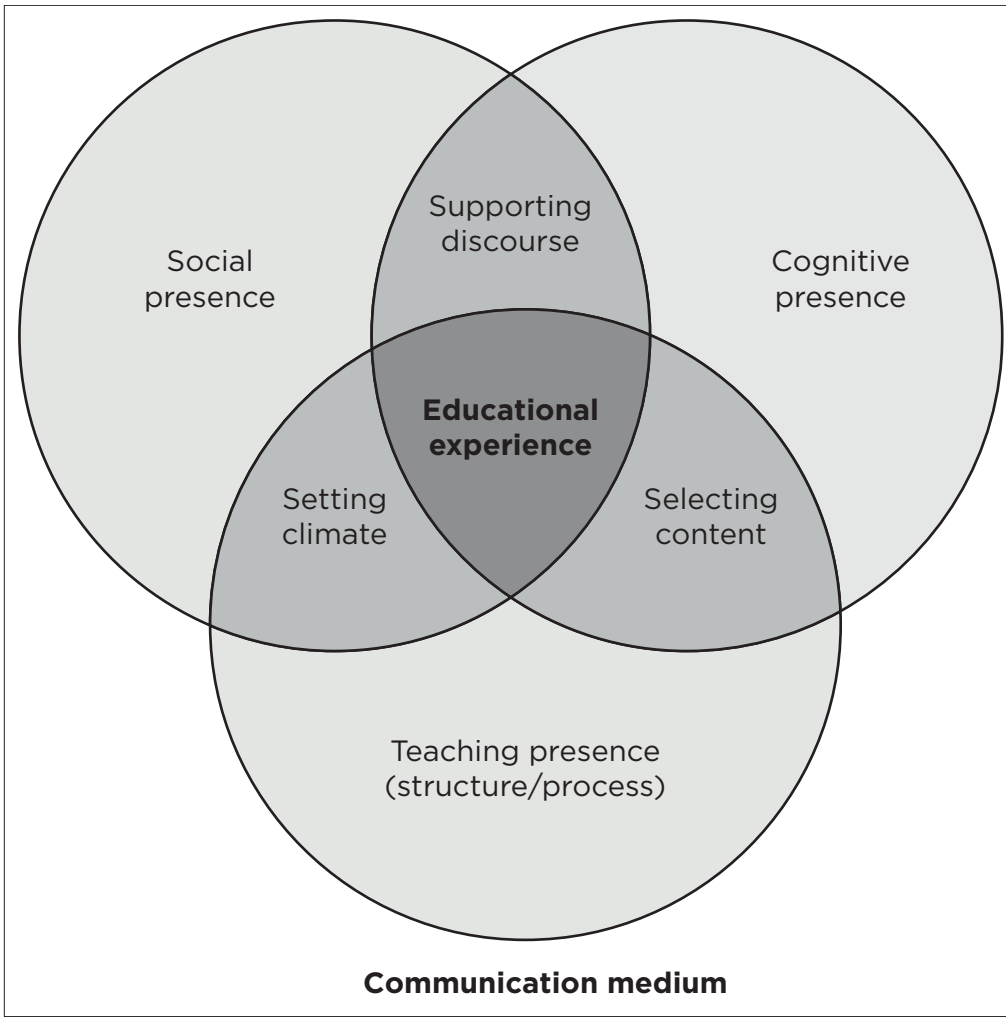
Scott et al. (2016) assert that Web 2.0 tools can also be used to create teaching and learning ecologies. These Web 2.0 tools include social networking sites such as Facebook, blogs, microblogs, for example Twitter, wikis, social bookmarks and web-based office tools such as Google tools

that can be documents, presentations and calendars among others (Scott et al. 2016). Through the enabling of the IoT environments, social media platforms are increasingly being used for teaching and learning. Atzori et al. (2012) theorise on the intersection between the IoT and social media as a networking paradigm that they call SIoT by means of simulations. Krutka et al. (2017), advocating for the development of social media pedagogies, explored the successes and shortcomings of using Twitter in pre-service teacher methods course. Some of the successes included the fact that the experience opened up possibilities for the pre-service teachers to use social media pedagogies in their future classrooms. The shortcoming of this particular Twitter integration in the methods course was that there was less structure and organisation. It seems more research is required to establish the effective affordances of some of the social media platforms in teaching and learning. Another teaching and learning social media tool commonly used is mobile instant messaging (MIM). One example of MIM is through WhatsApp. The advantages of using MIM for teaching and learning, according to Tang and Hew (2017), are based on the affordances of being temporal, user-friendly, multimodal and less costly. The teaching and learning platforms created through the use of the Web 2.0 tools allow students to (1) communicate, (2) post, edit and sort text and files, and (3) view the messages and content communicated, posted, edited and sorted by other users, among other affordances (Scott et al. 2016). Despite the teaching and learning possibilities presented by the use of social media platforms, there are some challenges that are experienced. The use of improper language, intermittent Internet connections, unequal student access to computers and other devices, interference with personal lives, seem to be some of the challenges that come with the use of social media platforms as instruction modes (Tang & Hew 2016). Generally, the use of these platforms is informal and Scott et al. (2016) recommend the development of Web 2.0 tools in enterprise social networks that are more private. With these networks, teaching and learning through social media platforms can be more formal and private for designated users. Other challenges that arise in the use of the IoT-enabled tools for teaching and learning are questions of how to ensure satisfaction by users, learner engagement and participation, learner critical thinking and social presence. In the next section, we discuss some of the strategies used to improve the social aspects of teaching and learning when classroom interactions are enabled by the IoT tools.

Strategies to ensure social presence in online courses

Borup et al. (2012) assert that online courses come with a sense of isolation. However, online courses open up immense opportunities for students in remote areas and for those who find convenience in asynchronous modes of

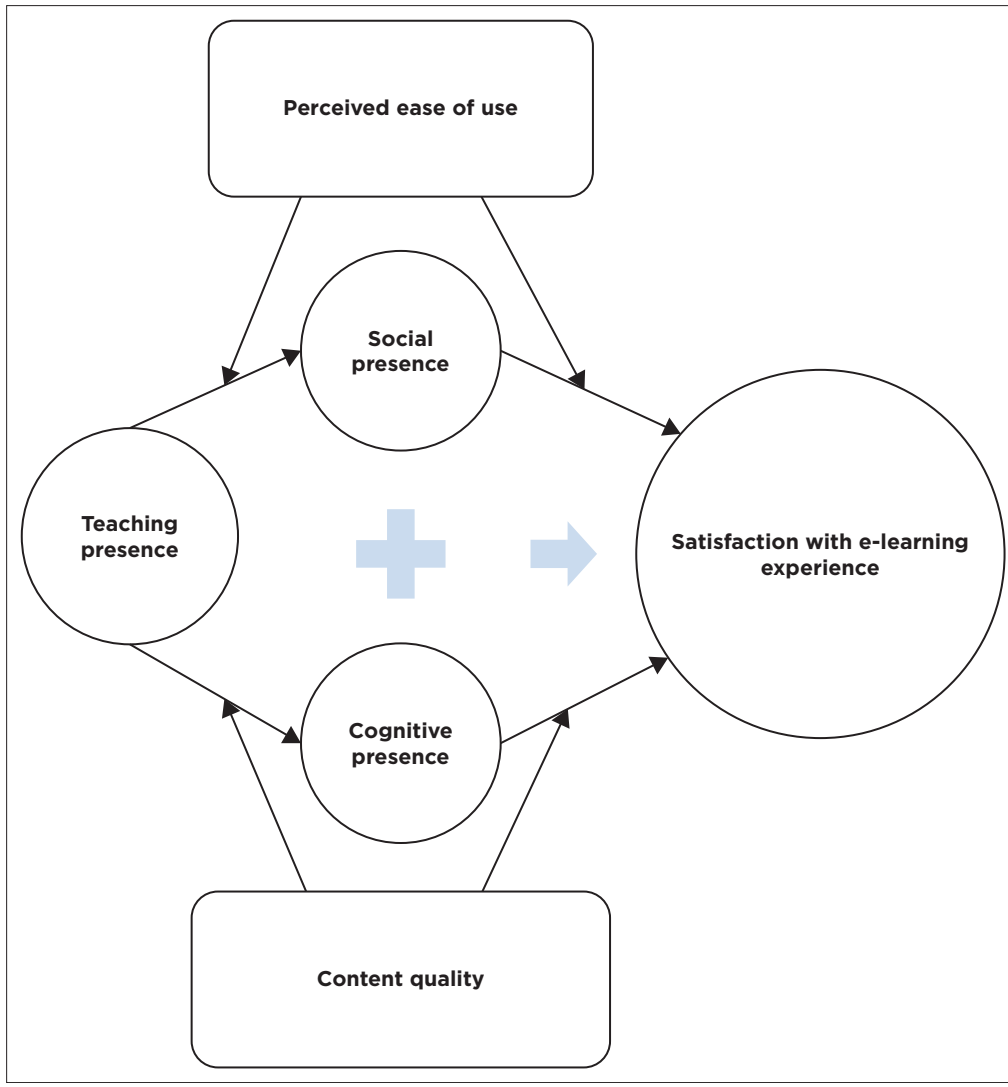
teaching and learning (Best & MacGregor 2017). In addition, the increasing adoptions of LMSs by HE result in the use of blended modes of instruction comprising both F2F and online classrooms. We will now discuss some of the ways that have been used to ensure that students experience social presence and other forms of presence for engaged learning and affordances for active participation. From the literature reviewed (Armellini & De Stefani 2016; Borup et al. 2012; Ke 2010; Lowenthal 2010; Saadatmand et al. 2017), we realised that social presence is most effective when used with other forms of presence, which are teaching presence and cognitive presence. The concept of presence used in the studies is rooted in the CoI framework by Garrison et al. (2000) in Figure 4.1.



Source: Adapted from Garrison et al. (2000:3).

FIGURE 4.1: Community of Inquiry framework.

What can be implied from the framework in Figure 4.1 is that instructional designers for courses should ensure rich educational experiences for students by designing for effective social presence, cognitive presence and teaching presence (Ke 2010). While the original CoI was text-based, the IoT has enabled the framework to be applied in contexts where multimedia is used such as online classrooms. However, Lee et al. (2021) have extended the CoI framework for e-learning to include three more variables which are perceived ease of use, content quality and satisfaction with e-learning experiences as illustrated in Figure 4.2.



Source: Adapted from Lee et al. (2021:3).

FIGURE 4.2: An extended community of inquiry model.

The CoI model proposed by Lee et al. (2021) acknowledges other factors that are at play in VLE. Therefore, the goal of instructional design is to achieve and build an effective CoI. Some of the factors that positively influence social presence and learning satisfaction in online classrooms include media integration and instructor's quality (Kim et al. 2011). One of the most common media used to enhance social presence experiences is the use of videos in synchronous, semi-synchronous and asynchronous instruction modes (Borup et al. 2012; Szeto & Cheng 2016; Wang et al. 2016). Borup et al. (2020) assert that videos make instructors more real, present and familiar. Lowenthal (2010) combined text and digital storytelling to improve the CoI and particularly social presence. Social media platforms enable the use of multimedia for teaching and learning and help to build CoI. Wang et al. (2016) mention that the use of WeChat, for example, allows synchronous, semi-synchronous and asynchronous interactions using text, audioconferencing and videoconferencing to support social presence, teaching presence and cognitive presence. We conclude this section by saying that the IoT-enabled teaching and learning in HE should be guided by sound frameworks that ensure engaged learning made possible by authentic interactions.

Transforming teacher education through the Internet of Things and social presence

In this section, we discuss the affordances made available by the IoT and social presence in transforming teacher education. The trends in the past decade show that universities are increasingly redesigning courses to place the IoT at the centre of the students' learning experiences (Kortuem et al. 2013). Both distance and F2F courses are transitioning into online platforms. The available IoT tools show that courses can be wholly or partly facilitated through online modes of instruction. In addition, online courses can be facilitated in synchronous and asynchronous ways or both. Therefore, in one form of the blended models, students can study online while others are studying through the F2F mode in the same course (Best & MacGregor 2017; Szeto & Cheng 2016). Similarly, through another form of blended learning, students can study through both F2F and online modes. It has become an expectation of teacher education for pre-service teachers to learn how to use these different modes of instruction in their future classrooms. Graziano (2017) describes how pre-service teachers were able to make lessons interactive and fun by using the concept of flipped classrooms. Graziano (2017) elaborates by saying:

> In a flipped learning model, the instructor creates video lectures, screencasts, or podcasts that teach students academic content outside of class, freeing up valuable class time for more engaging and collaborative learning. (p. 121)

Based on the affordances presented by social media to create teaching and learning ecologies, pre-service teachers are expected to learn how to use 'social media pedagogies' and more so, *responsibly* (Krutka et al. 2017). With all these transformations afforded by the IoT, the challenge is for both teacher educators and pre-service teachers to stay abreast with the emergent 4IR technologies (Best & MacGregor 2017). The adoption of LMS and its affordances already discussed, enable HE, including teacher education, to use the IoT-mediated teaching and learning for courses based on hands-on activities that require the handling of materials and equipment. Best and MacGregor (2017) assert that it is achievable to successfully transition a practical course involving hands-on learning activities to an online environment. However, in the study by Best and MacGregor (2017) involving a Design and Technology Education course, the pre-service teachers who were wholly enrolled for online instruction had the design and technology kits sent to them physically. The discussed 4IR-based teacher education transformation has implications for both the pre-service teacher placement for practicum and the schooling system. Waters and Russell (2016) explored the use of virtual practicum placement and reported that pre-service teachers chose this form of placement for convenience. The use of the CoI namely, social presence, teaching presence and cognitive presence, was seen to be very critical in assisting pre-service teachers to develop subject matter expertise through online instructional modes (Yang 2017). The mentioned presence can be achieved through instructor frequent engagement, use of various modes of communication including chatrooms, discussion forums, videoconferencing and emails and use of virtual and F2F engagements (Hajibayova 2017; Szeto & Cheng 2016; Yang 2017).

Limitations of the study

The study made an attempt to explore the transformation of teacher education in the context of the 4IR through the IoT and social presence conceptual framework. However, the scope of the findings is limited by the study design that used a sample of 20 articles published between 2010 and 2019 from one database. We acknowledge that there are more 4IR concepts other than the two (IoT and social presence) that were used in this study. We take cognisance of the fact that the findings could be different if other databases, methods of sampling and publication timeframes of the sources were used. However, we were transparent in the manner in which we selected the articles that were used in the meta-analysis. Therefore, the findings of the study can be treated as a case study that adds insights to the scholarly body of literature on how teacher education and HE are transforming in the context of the 4IR and the advent of the IoT.

Conclusion

The advent of 4IR has ushered in a new era in which pre-service teachers' preparation is modelled around the IoT resulting in the incorporation of online instructional modes into the traditional F2F classrooms and traditional distance education. With the IoT becoming increasingly ubiquitous, the use of blended modes of instruction, LMS and Web 2.0 tools such as social media platforms, blogs and web-based office tools marks a departure from the dominance of F2F lectures and compels universities to reimagine the nature and the meaning of contact hours, thereby slowly bridging the gap between distance learning and on-campus learning. The careful use and selection of multimedia which form the backbone of LMS and Web 2.0 tools by teacher educators result in the establishing of social presence necessary for interaction, participation and engagement taking into account that learning is more effective in social settings. However, the literature reviewed revealed that social presence coincide with other forms of presence: teaching presence and cognitive presence.

This study recognises three important theoretical frameworks that are important in explaining teaching and learning in virtual classrooms enabled by the IoT. These theoretical frameworks are the CoI developed by Garrison et al. (2000), the IoT and the SIoT. One recommendation made in this study is to challenge the methods course designers use to include elements that prepare teachers not only through IoT-enabled approaches, but also for the pre-service teachers to be able to use the IoT tools and approaches, in their future classrooms using pedagogies that ensure the teaching, social and cognitive presence. The immense opportunities presented by the use of VLE in teacher education do not signify that physical learning environments have become less important. Models for using the two approaches should be studied and developed. The use of VLE also brings social justice and access issues to fore because not all communities have IoT resources to support effective social presence. This study recommends further studies on the IoT affordances within a reality where some schools in disadvantaged conditions lag behind in terms of the 4IR developments. Virtual practicum placements for pre-service teachers have also become a possibility. Based on the limitations of the study, a recommendation is made to conduct a quantitative study on the same to investigate the transformation of teacher education using more 4IR dimensions in addition to the IoT. Moreover, the study calls for further research to explore how South African teacher training programmes prepare pre-service teachers to use IoT-based pedagogies and social presence in their future classrooms. This recommendation points to the need to capacitate teacher educators to perform the task of preparing teachers in pedagogies to be implemented in 4IR environments. Universities should support student-teacher educators through continuous professional development and keeping e-learning

resources abreast with technological advances of the day. Teacher educators can capacitate themselves by engaging in scholarship of teaching and learning in which they conduct research in their own practice and develop strategies and solutions for the challenges identified.

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Chapter 5

Teacher efficacy in the 4IR: Telling stories digitally

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Abstract

Teacher efficacy refers to the teachers' beliefs about their own competence in curriculum delivery. Teacher efficacy is currently challenged by the diverse learner populations that South African schools are faced with. Multiculturalism, multilingualism and technological transformation render teaching a frustrating process as teachers have not been trained to deal with these new challenges. Traditional teaching methods are losing momentum as children are exposed to various kinds of technologies outside the classroom environment. It is, therefore, important to revisit the teaching strategy in the BEd curriculum to prepare student-teachers for the challenges that await them in the 4IR classroom. This chapter suggests the inclusion of digital storytelling as a teaching strategy in the teacher education curriculum. Digital storytelling can be defined as a narration of a story by using multimedia such as cameras, video recorders, computers and smart boards. This method gives learners an opportunity to bring their own funds of knowledge and

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construct a cross-cultural curriculum that gives teachers a foundation upon which they can develop an inclusive curriculum, thus boosting teacher efficacy.

Introduction

Education systems globally are currently faced with challenges that call for transformation and innovation in preparing teachers for the teaching profession in the Fourth Industrial Revolution (4IR). In addition to the challenges of multiculturalism and multilingualism, South African teacher education is faced with the challenge of preparing teachers for the 4IR. The concept 'Fourth Industrial Revolution' was created by Klaus Schwab to describe a 21st-century world through technological transformation (Ross & Mynard 2021:159; Schwab 2017:8–23; Xu, David & Kim 2018:90). Technologies that include, among others, AI and IoT bring shifts in people's lifestyles (Kayembe & Nel 2019; Ross & Mynard 2021:159). Artificial intelligence refers to the ability of computers and other machines to learn and respond the way human beings do (Alsedrah 2017:3). Internet of Things refers to a digital network in which machines interact between and within each other to share information (Karabegovi & Husak 2018:72). This implies that the way in which people lived and shared information is also changing.

In the education sector, teachers are under pressure to alternate traditional offline lifestyles with the use of digital technologies (Xu et al. 2018:90). In learning environments, the emergence of advanced technologies also gave birth to what is commonly known as blended learning. Teachers who are in practice currently have not been professionally equipped to use new technologies in teaching and learning. Traditional teaching methods are also becoming less relevant because school learners are exposed to various kinds of media devices such as laptops, smartphones, tablets, digital cameras and home video game consoles such as PlayStations or Xbox at an early age. Media devices are now so easy to use that even a two-year-old child can start using them with little guidance from an adult (Magano & Ramnarain 2015:65).

The outbreak of the COVID-19 pandemic also shed a new light on the importance of multimedia in teaching and learning. A Grade 12 student, Azikile Mathule, was interviewed on the South African news channel, eNCA (also known as eNews Channel Africa), about the effects of the pandemic on the class of 2020 and responded:

> 'The world of today is doing things digitally. Why don't we adjust to it and be optimistic about it? [...] We the class of 2020 are the pioneers of the Fourth Industrial Revolution.' (Mathule, Grade 12 student, 31 May 2020)

The pandemic forced teachers and learners to use apps such as WhatsApp, Google Classroom and Zoom to teach, learn and submit tasks. This

phenomenon, swiftly turned curriculum implementation towards a new direction of digital learning across all the school phases.

Background

The 4IR calls for transformation in South African teacher education. Challenges faced by teacher education with regard to the usage of technologies in education are among others, equipping teachers and learners with new skills that are relevant for the 21st-century; enabling people to access online content and practice as well as transforming learning to be more learner-centred and fun (Kayembe & Nel 2019:90).

The present-day leaners are not just information gatherers but information creators as well (Robin 2008:221). Young people construct knowledge by means of multimedia devices which implies that they are stimulated and motivated to learn by incorporating these tools in learning environments. The challenge, however, is that teachers and learners situated in many rural areas do not have access to these gadgets, are not well-equipped to teach and learn online, and the areas they are working in might not have Internet connections. Challenges brought by the COVID-19 pandemic to learning environments already bear witness to the demise of teachers and students who live in rural areas. Online teaching proves to be a serious threat to quality teaching and learning in these areas. It is therefore, evident that digital technology poses a threat to teacher efficacy.

Blended learning can be described as convergence between electronic and traditional instruction (Graham 2004:533). According to Chew, Jones and Turner (2008:40), 'blended learning involves the combination of two fields of concern: education and educational technology'. Teacher education in the 4IR should prepare teachers for teaching in technological environments and using electronic resources.

Learning environments that integrate traditional methods with electronic resources are also effective in teaching and learning (Bryan & Volchenkova 2016:24). In South African rural schools most of the learners are from low-income families and communities and lack of resources is a serious challenge. Also, teachers at these schools are not well-equipped to improvise and diversify their teaching strategies. This implies that teacher education should heed the call to train teachers to differentiate their pedagogies and include technologies. A differentiated curriculum helps teachers to develop creative skills, caters to the learners' varying learning styles and boosts the teachers' self-efficacy.

Theoretical framework

The concept of self-efficacy emanates from Bandura's Social Cognitive Theory (Bandura 1997). It refers to individuals' beliefs about their abilities to

successfully perform certain functions in various settings. Teacher efficacy refers to teachers' beliefs about their personal ability to perform their duties in school settings (Skaalvik & Skaalvik 2007:612). It involves confidence and effectiveness in delivering learning content to the learners in such a way that the desired learning outcomes are achieved. It is about what teachers believe they 'can' do rather than what they 'will' do. The word 'can' refers to a judgement of capability, whereas the word 'will' communicates intention (Bandura 2006:308).

Teacher efficacy influences the teachers' behaviour in the learning environment, consequently, their students' motivation and performance too (Klassen & Chiu 2010:741). It 'affects the effort they invest in teaching, the goals they set, and their level of aspiration' (Tschannen-Moran & Hoy 1998:783). Teachers with low self-efficacy experience more difficulties in teaching, higher levels of stress, lower levels of resilience and persistence when things do not go according to plan, as well as lower levels of job satisfaction (Tschannen-Moran & Hoy 1998:783; Betoret 2006:534; Skaalvik & Skaalvik, 2014:75). When teachers feel inadequate, they become demotivated, lose interest in the teaching profession and because of burnout, some eventually resign to pursue other fields. In order to reduce the intensity of brain drain in the teaching profession, teacher training should equip teachers with strategies to cope with teaching the generation of the 4IR.

The 4IR poses challenges for the teaching profession because teachers need both internal coping resources such as self-efficacy and external coping resources such as teaching aids in order to perform their duties optimally (Betoret 2006:5220). Technological innovations accelerate people's lifestyles, work and social relations and infrastructure (Ross & Mynard 2021:159). This implies that in the 4IR, digital technologies are essential teaching resources that should augment traditional teaching methods such as lecturing and written print. Content can be narrated digitally and transcribed to written print. This however, calls for innovations in teacher education and training as well as the provision of the relevant technological resources in all schools, including schools in rural areas.

There are various theories that underpin narration or storytelling as an effective practice in learning and development including among others, Vygotsky's socio-cultural constructivism, Bandura's social learning theory, Gardner's theory of multiple intelligences and Bruner's narrative construction of reality theory.

Language plays a central role in Vygotsky's socio-cultural theory. Vygotsky (1978:30–31) asserts that learning is a social collaborative process that takes place by means of a language. It is through interactions with other people that learners create their own meaning and modify their languages. When learners from different cultures and who speak different languages share their stories,

their cultures and languages converge. This implies that stories bridge cultures, promote prosocial behaviour and foster global citizenship. This implies that storytelling is an essential component of learner-centred teaching. Bandura (1977) also emphasises that cognitive development takes place through communication and interactions among people in social contexts. Storytelling creates such social contexts for teachers and children in the learning environment. It also affords children an opportunity to learn in accordance with their learning styles, preferences and intelligences (Gardner 1993). Bruner (2004:691–709) maintains that life is a narrative. This means that in all human interactions and communications, stories are being created and narrated. Teaching and learning take place by means of human interactions. This implies that in everything that happens in the classroom, a story is being narrated. In all subjects, these stories carry cultural norms, values and attitudes that are imparted to the young generation. Stories narrated by children also carry these cultural toolkits from their social contexts. A story is a powerful asset to 'develop both character and literacy amongst young children' (Desai & Parker, 2018:212). As the 4IR created shifts in human interactions and communications, traditional storytelling methods have also changed to include digital methods.

Digital storytelling as a teaching strategy

A digital story is a 'digitally constructed personal narrative' that unearths significant lived experiences of the narrator through multimedia (Lum 2013:51). It is a 'narration of a story by using digital equipment which includes among others, cameras, video recorders, computers and smart boards' (Babane 2018:134). Telling stories was often associated with language teaching; however, recent studies show that it is an effective cross-curricular teaching strategy that provides learners with an opportunity to learn according to their own contexts regardless of their varying social backgrounds (Chubko 2020; Gursoy 2021:110). It is also an effective therapeutic strategy that helps children to express their thoughts and emotions and helps them deal with them amicably. Telling stories digitally is also an appropriate multimodal technological strategy for handling multicultural classrooms because it allows diverse learners to reveal their lived experiences in the classroom environment and promotes an understanding of difference (Condy et al. 2012:279; Stewart & Gachago 2016:529). The varied learning styles and intelligences are accommodated because a digital story is multimodal as it involves audio-visuals, music, talking, etc. Allowing school learners to create and share stories digitally makes curriculum differentiation easier for teachers, thus boosting their self-efficacy.

Personal storytelling encourages children to be creative and express the way in which they understand the world. It is a prosocial pedagogy that enables children whose lives have been differently constructed to share their funds of knowledge and learn from one another in the contemporary audio-visual

language (Benmayor 2008:188; Stewart & Gachago 2016:529; Pratt, 2020). Through digital storytelling, children produce digital information that can be shared technologically both locally and internationally and thus promoting global citizenship (Truong-White & McLean 2015:7).

It involves the use of cameras, mobile phones, video recorders, computers and smart boards to narrate a story. The story is narrated by blending personal narratives with multimedia content, such as digital images, music, video clips, voice-overs and computer-generated texts (Babane 2018:134; Lambert 2013; Ranieri & Bruni 2013:628). Narrating stories digitally enables learners 'to find their voice and to … construct a cross-cultural community for empowerment in (the) classroom' (Benmayor 2008:188–189). This method therefore also empowers learners to construct their own curriculum content from their own cultural toolkits, which assists teachers in curriculum development.

Digital narration of stories is designed from a constructivist perspective that encourages learners to construct new knowledge and develop problem-solving, creative and critical thinking skills across the curriculum (Ohler 2013:7; Sadik 2008:488). It is a method that can be used effectively across the curriculum because all learning areas should draw curriculum content from the school contexts. This implies that school subjects should tell stories that are embedded in the norms, values and attitudes of the societies and communities in which the school is situated. As Ohler (2013:7) asserts, 'learning communities are primarily storytelling communities'. In order to keep up with the 4IR, teachers should be trained to translate these stories into digital content.

Children can also create a story as a group by using their mobile phones. They can capture moments, download images and create a fictional or real-life story together and later share it with their classmates (Ranieri & Bruni 2017:628), thus promoting a cooperative and prosocial learning environment. Individuals or groups should first think about which story they want to tell, then decide on the media they want to use. The story can be shared in class in about 2 min to 5 min. When sharing their stories, learners use their own vocabulary and attach meaning to their stories in accordance with their cultural toolkits and the ways in which their lives have been socially constructed. This promotes cultural consonance.

Every life event is a story, ranging from relating short events such as losing a homework book to long narrations about one's lived experiences or autobiographies (Bruner 2004; Lambert 2013:15). This means that storytelling content is always available in people's daily lives and that when we narrate stories, we communicate life as we experience it in our cultural and linguistic contexts. The same phenomenon, is experienced and interpreted differently by individuals and groups from diverse contexts. This means that our stories cannot be identical. Teachers should be equipped to differentiate their pedagogies with this notion in mind.

Storytelling can promote collaborative practices and prosocial behaviour in various school contexts. It promotes self-expression in children with regard to their identities, a practice that supports cultural consonance. As Chimamanda Ngozi Adichie asserts, 'Stories matter [...] Stories can empower [...] and repair human dignity'. These also include immigrants, second-language speakers and children with other language barriers. Using mobile phones for educational purposes encourage children to use their mobile devices creatively and responsibly and promotes a participatory culture (Jenkins et al. 2009; Ranieri & Bruni 2013:217). According to Jenkins et al. (2009:3), a participatory culture is a culture that alleviates barriers to self-expression through art, provides strong support for creating and sharing one's creations with others and involves mediation by the more knowledgeable other in the group. It provides children with a feeling of social connectedness and worthiness because they believe that their own creations matter in the learning environment. It is therefore, important that teacher training prioritises media literacy in order to equip student teachers to include multimedia in their pedagogies in all school contexts.

It is my contention that the curriculum for South African university and college student teachers should incorporate digital storytelling as a teaching method to make learning more learner focussed, fun and culturally relevant in order to prepare students for the 4IR classroom. Most of the current generation of teachers in practice were trained in traditional methods before the 4IR; therefore, it is essential that the current teachers in training are provided with the theory and practice of digital storytelling as a teaching strategy.

Implications

Digital teaching has serious implications for low-income and rural schools. The notion of digital instruction is more successful in urban schools because the schools are well-equipped, have electricity and network connectivity and security measures are in place. The idea sounds far-fetched for schools that are situated in low-income and rural communities. Some of these schools are still struggling to get basic needs such as food, proper infrastructure and transport to school. Placing technological equipment such as computers and smart boards in economically challenged environments could also pose a safety challenge. Given the rate of vandalism and theft in many South African schools, improvisation in the use of ICT needs to be considered. So, given the issues mentioned here, how can digital storytelling be implemented in these schools?

Trucano (2013) suggests that the best technology is a sustainable one that is available in these communities. He suggests that mobile phones are commonly available in low-income communities and can be used as tools for digital teaching and learning. These gadgets are important in early childhood

development as they contain games that promote emergent mathematics and literacy (Flannery et al. 2013:10; Gomez et al. 2013:225; Wagner 2016:7). They can be used as assets to gather data in order to enhance children's understanding of subject content in the classroom. This suggestion however, is still unrealistic for many South African rural communities as many families cannot afford smartphones for their children. Also, if teachers use mobile phones to teach while learners do not have them, teaching and learning would remain teacher-centred. Given the circumstances and lack of technological resources in these communities, it would not be viable for teachers to provide quality education by means of digital devices. These realities therefore, call for swift Government intervention in providing technological support in these communities.

Conclusion

This chapter explained the need for teacher education to equip teachers to differentiate their pedagogies in the 4IR classrooms in different South African school contexts. It has shown the importance of digital storytelling across the curriculum and how equipping teachers with digital teaching strategies can boost their teacher efficacy. Digital storytelling enables learners to learn according to their diverse learning styles, develop their multiple intelligences and participate in curriculum design and development. It also encourages identity self-expression, sustains cultural consonance, gives a sense of belonging to peers and fosters prosocial behaviour. For rural children however, digital learning still remains a dream. This implies that rural communities should be technologically empowered and supported in order for them to realise this dream.

Chapter 6

Re-imagining teacher professional development for the future South African public schooling context

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Abstract

The advent of the Fourth Industrial Revolution (4IR) is mainly characterised by extraordinary technological advances that come with fundamental changes in the way we live, work and relate. These changes are influencing all aspects of our life, particularly the education space by way of challenging traditional principles of teaching and learning. Education systems the world over are preoccupied with strategies that speak to advancements in curricula transformation and development to meet the 4IR demands. The role of the teacher is set to change dramatically in future classrooms in order to keep pace with the technological advances and skills required for the 21st-century learner. This chapter argues that a parallel discussion that considers the role of teacher professional development in response to these new dynamics is necessary. The purpose of this chapter is to consider how the 4IR has and will continue to influence the role of teacher professional development in the

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South African public schooling context. Currently, the field is imbued with various forms and content challenges that make it difficult to provide meaningful experiences of teacher learning. Using a critical review of literature, this chapter interrogates the opportunities and challenges of teacher professional development in South Africa ahead of the 4IR.

Introduction

The literature that tries to conceptualise the idea of the Fourth Industrial Revolution (4IR), what it means and how different sectors can respond to it is quite extent (Butler-Adam 2018; Schwab 2016; Xing, Marwala & Marwala 2018). Industrial revolutions date back to the 18th century where agrarian societies increased production and operational efficiency through mechanisation. This saw the inception of the First Industrial Revolution (1IR) where water and steam power proliferated production. The second was characterised by the use of electric power and the third built onto the second by introducing electronic and information technology to automate production (Schwab 2016). Today, the world over, the advent of the fourth revolution, popularly known as the 4IR is topical and is believed to be 'blurring the lines between the physical, digital and biological spheres' (Schwab 2016:2). In other words, the human–technology interaction is rapidly increasing and technology is fast assuming human characteristics. Thus, 4IR digitisation is manifest in things like IoT, robotics, virtual reality (VR) and AI. According to Xing et al. (2018), these 4IR inputs are fundamentally changing, and will continue to change, how business is conducted in the marketplace, the production and distribution of goods and the global economy at large. The 4IR is in a class of its own and when compared to previous industrial revolutions, 'has no historical precedent' (Schwab 2016:1). To say the least, the 4IR is unveiling a new world order that will affect every sector in all parts of the world.

Research on the 4IR (Ali & Ismail 2020; Schwab 2016; Xing & Marwala 2017; Xing et al. 2018) is consistently saying that this digital revolution is a bittersweet development as it simultaneously presents new and exciting possibilities and also presents an uncertain future with unprecedented challenges. The education sector is one that has already begun to experience the impact of the 4IR as questions about how to respond are taking centre stage. While there are a lot of potential opportunities anticipated, education systems across the world are contemplating how they will respond to the challenging aspects of the 4IR. One certainty is that there is need for transformation in terms of what schools are teaching and how that knowledge is to be imparted. According to Xing et al. (2018), there is need for retraining and educating people differently through increasing access to education of a higher quality that matches the knowledge and skills demands of the 4IR. With these

developments comes a growing recognition that institutions of higher learning and schools will increasingly become hubs of innovation generation and its incubation (Butler-Adam 2018; Ilori & Ajagunna 2020). Therefore, it goes without saying that teachers are a pivotal piece of this revolution and have an enormous responsibility of preparing relevant and functional learners for the 21st century.

The prevailing backdrop is that we have an enduring challenge of poor teacher quality, which can well be deemed 'the nub of the problem [that] the South African education system faces' (Prew 2013:70). As a result of poor teacher quality, the quality of teaching in the majority of South African public schools has been appalling as teachers struggle with basic instructional practices (CDE 2011; Chisholm 2005). What this suggests in the new context of the 4IR is that reskilling and retraining of teachers in the South African public schooling context becomes an immediate imperative. It is, however, important to note that the professional development of teachers in South Africa, since 1994, has been a subject of contention. Innumerable teacher development (TD) activities and intervention programmes have been implemented and have failed to translate to significant improvements to teachers' instructional practices, let alone learners' performance (Dlamini & Mbatha 2018; Gumbo 2020; NEEDU 2013; Shalem & De Clercq 2019). This chapter is, therefore, an attempt to bring to the fore the implications the 4IR has on the already overwhelmed teacher professional development field in South Africa. I argue that any attempt at implementing teacher professional development activities or programmes needs to be mindful of the changes in the context of teachers' practice and should begin to adapt and mutate in order to suffice the retraining and reskilling of teachers to fit the mould of the 4IR.

To address this key problem, this chapter extends deliberations on how the education sector, particularly the field of teacher professional development is affected by the 4IR. To achieve this aim, this chapter is guided by the following questions:

- How is the 4IR influencing the role of the teacher in the South African public schooling context?
- Is the present-day South African teacher prepared for the 4IR classroom?
- What does the advent of the 4IR mean for teacher professional development in South Africa?

In consideration of the above questions, this chapter sets out to illuminate, through a comprehensive review of existing literature, how the 4IR is inevitably influencing the role of the teacher, particularly in the South African public schooling context. I will also explore the terrain of teacher professional development in South Africa and outline factors that are confronting this field in terms of its preparedness to provide meaningful TD for the 4IR classroom.

Review of related literature

The 4IR and education

As the world braces for new ways of working, living and relating because of the 4IR, education is increasingly pushed at the centre of it all in order to advance knowledge regarding human development. Taking into consideration these industrial revolution advances, however, requires education systems around the world to reconsider their approaches, transform and adapt in a way that integrates insights from these contextual demands. This is consistent with Lamprini and Bröchler (2018) who argue, in fact, that education systems should be the vehicle through which the 4IR advances are introduced and applied. In other words, education needs to be in a position of leading the 4IR innovation and, at the same time, support the development of appropriate high human capital skills. What this suggests is that the education sector needs to take cognisance of the nature of skills and knowledge required by a 21st-century learner and then align them with the curriculum and pedagogical constructs. The reality is that the world has changed, the learners have changed and so too should the learning environment, the curriculum and the teaching methodologies (Hussin 2018).

The 4IR is set to configure the context of teachers' practice and one of the ways in which this will happen is through curriculum reform. There is consensus in the literature (Darling-Hammond, Hyler & Gardner 2017; Ilori & Ajagunna 2020; Menon & Castrillón 2019; Oke & Fernandes 2020) that the totality of learners' experience at school has to match with the required skills in the job market. Many education systems across the world are deliberating on moves towards curriculum reform to ensure learning adapts and is abreast with the 4IR-induced advancements. Significant updates of the curriculum will be required to ensure that schools become centres of knowledge and innovation creation. However, much of these 4IR-appropriate curricula ideas are yet to be implemented in curriculum delivery, particularly in Africa (Ilori & Ajagunna 2020; Lamprini & Bröchler 2018). For years now, since independence, the South African education system has been emphasising the need to incorporate into the curriculum subjects that are taught using a problem-based pedagogy where 21st-century skills such as critical thinking, problem-solving, effective communication and self-direction are prioritised. In 1998, this saw the inception of Outcomes-Based Education (OBE) that foregrounded a learner-centred pedagogy and it was a dismal failure as the context was not prepared for such a situation (Shalem & DeClercq 2019). One of the reasons the implementation of this curriculum failed was because TD could not develop teachers to manage pedagogical practices that were required by the OBE curriculum. It is important to note that most of the 4IR skills align well with a learner-centred pedagogy curriculum like OBE. This begs the question: what will TD in South Africa do differently to ensure that the 4IR-appropriate pedagogies are implemented in the classrooms?

While there is an urgent need for the education sector to be proactive and play a leading role in the advancement of human knowledge for the 4IR, Lamprini and Bröchler (2018) note with concern how, when compared to other sectors, education seems to be the least responsive and innovative. Oke and Fernandes (2020) collated the views of key stakeholders with regard to the implications of the 4IR and they found that the general impression was that education systems are not yet prepared to conduct teaching and learning in a way ideal for the innovation that comes with the 4IR. Education practitioners are conflated and conceive the 4IR as one historical epoch that will severely disrupt how they teach and engage with learners. Despite these negative perceptions, opportunities for the education sector to take advantage of the innovations associated with the 4IR are plenty. However, these may not be obvious for some education systems that have not been able to keep up with the digitisation. This is certainly the case for many African countries. It is, especially, the case in South Africa where some school communities have not yet fully embraced the electronics and communication technologies that came with the Third Industrial Revolution (3IR) (Iwuanyanwu 2019).

What can generally be agreed upon is that these are uncertain times. There is, as a result, a lot of speculation about our future in relation to the 4IR. Butler-Adam (2018) points out that there are two views with regard to the 4IR. The first one is a pessimistic view that consists of critics who are apparently conscious of the encroachment of the 4IR yet ill-disposed to it. This group of pessimists consider the 4IR a serious threat and challenge to human talent as AI will assume and overtake a considerable fraction of human roles. This perception is especially fuelled by the realisation that digitisation of products and services is a reality where 'the factory floor is moving towards self-regulating production that can be adapted to individual customer demands and has self-learning capability' (Xing & Marwala 2017:12). The 4IR brings along AI and, over time, this increase in automation is feared to render human skills irrelevant resulting in a loss of employment for many people. In the education sector, there is even speculation that the teacher will no longer be needed as learners can access school knowledge in various e-learning platforms. The COVID-19 global pandemic has actually pushed innovation and creativity in the development and fast adoption of the virtual classroom. Such developments attest the possibility of the physical classroom and the teacher becoming obsolete.

The second perception to the 4IR is an optimistic one where proponents believe that while the 4IR is accompanied by drastic changes in the way people live, work and relate, it offers opportunities for the advancement of human knowledge as we find ways to implement, manage and work alongside the technology (Butler-Adam 2018). Industrial revolutions came about to increase productivity through more efficient mechanisation. In the same way, optimists argue that the 4IR will bring better standards of living as the world economies are made more efficient and productivity is eased and increased

through the use of self-adaptive, self-regulating and self-learning AI (Schwab 2016; Xing & Marwala 2017). The nature of the 4IR developments will impact changes to all aspects of our lives, more so in education.

However, as it stands, the education sector, especially in the African context, is far from being prepared for the 4IR (Oke & Fernandes 2020). In South Africa, there is great anticipation about the digital antics that come with the 4IR seen in the growing urgency to conceptualise the idea of the 4IR and what it means for the curriculum in different educational sectors. Although there are many potential opportunities for growth and development from the much-anticipated 4IR, research (Butler-Adam 2018; Menon & Castrillón 2019) shows that the South African education system is far from the mark. In fact, adverse effects such as the widening of the gap between the rich and the poor are imminent.

Xing et al. (2018) observe that the need for accelerated professional development is unquestionable. They argue this in the context of HE saying that the traditional view of the university lecturer as the custodian of knowledge and the student as a passive recipient is now inapt. What needs to be inculcated amongst lectures and students are factors like being more interactive, collaborative, critical thinking and problem-solving learning techniques that match the fast-paced innovation of the 4IR era. The same can be argued in the context of teacher professional development that has to support the development of what Darling-Hammond et al. (2017:6) call 'active and inquiry-based learning' where teachers encourage the use of pedagogies that allow learners to problem-solve, think critically and communicate well, both in the spoken and written (Butler-Adam 2018). In order for this to happen, teacher learning in various TD programmatic activities should be afforded an opportunity to engage in 'the same style of learning they are designing for their students' Darling-Hammond et al. (2017:6).

While this may sound encouraging and compatible with the demands of the 4IR classroom, it is important to mention that this will be very difficult to implement in the South African context. In what follows, I discuss the various factors that have proved to be enduring challenges in the South African teacher professional development field. I argue that these same factors undermine the preparedness of many South African teachers to adapt their pedagogical constructs to meet the 4IR demands. I also argue that unless we reimagine TD and adopt new approaches that allow for empowering pedagogies, we too will be outdistanced thus robbing future citizens of an opportunity to participate meaningfully in the global and digital economy.

The context of teacher professional development in South Africa

While this chapter is concerned with developing an understanding of how the 4IR influences the role of the teacher and what this means for the field of

teacher professional development in South Africa, it is of paramount importance to reflect on the current macro educational context within which teacher professional development is practiced. Many schools, particularly black schools, in South Africa are marred with challenges because of the poverty and societal disruption prevalent in the communities they serve (Mouton, Louw & Strydom 2012; Spaull 2019). Some of the societal problems include conflict, violence, vandalism, criminality, gangsterism, rape and substance abuse and these inherent community problems inevitably find their way into the schools (Leoschut & Makota 2016). The majority of black schools were poorly resourced and consequently, many of them were classified dysfunctional as evidenced by the collapse of the 'culture of teaching and learning' (Christie 2008). After the attainment of freedom in 1994, many of these schools remained largely dysfunctional because of high teacher and learner absenteeism, high learner ill-discipline that resulted in severe underperformance, high-grade repetition and high dropout rates (Christie 2008; Fleisch 2008; Leoschut & Makota 2016; Spaull 2019; Taylor, Muller & Vinjevold 2003). In addition to these challenging physical, socio-economic conditions and general contextual arrangements that significantly crippled effective teaching and learning, the South African education system also suffered from what Cross, Mungadi and Rouhani (2002) call grand philosophies and ideals that were not realistic given the contextual legacies and the particular circumstances in which the majority of schools were operating in. Curriculum reform, in particular, had a grand effect that complicated and distorted the system and Cross et al. (2002) note that:

> [*C*]urriculum reform in South Africa has resulted in several structural and policy tensions within the system. These tensions include: the vision *vis-a`-vis* the country's realities; symbolism *vis-a`-vis* mass expectations; the curriculum framework *vis-a`-vis* applicability, conditions of implementation and actual practice in schools; expected outcomes *vis-a`-vis* the capacity of teachers to translate them into reality. (p. 172)

Since then, teacher professional development in the South African public schooling context remains a challenge as tensions brought about by the numerous curriculum reforms persist. The literature (Geldenhuys & Oosthuizen 2015; NEEDU 2013; Shalem & De Clercq 2019; Van der Berg et al. 2011; Venkat 2019; Welch 2012) is clear that many attempts have been made to try and ensure the system and the teacher professional development field recover. Unfortunately, the system still suffers from the use of incoherent, ineffective and unsustainable programmes and practices (Geldenhuys & Oosthuizen 2015). In addition to this, there is generally poor uptake from teachers who struggle to translate what is learnt from TD into classroom teaching and learning (Dlamini & Mbatha 2018; Gumbo 2020).

Because teaching is a knowledge-based profession, any initiatives to professionally develop teachers ought to focus specifically on the different kinds of knowledge essential for professional practice (Darling-Hammond et al. 2020).

Teacher development initiatives in South Africa seem to be lacking in inculcating effective content knowledge, general pedagogical knowledge and pedagogical content knowledge in teachers. It has long been established in the literature (Christie, Harley & Penny 2004; De Clercq 2013; De Clercq & Phiri 2013; Maistry 2008; Taylor 2008, 2011; Venkat 2019; Welch 2012) that, much effort has been devoted to professionally develop South African teachers through various intervention programmes and activities. The disturbing reality, however, is that the majority of teachers seem not to benefit from these or show great take-up as they still struggle with content knowledge and its delivery, or what De Clercq and Shalem (2014) call basic content and pedagogical content knowledge.

South African teacher development interventions have failed to address specific teacher needs that are related to the stages of their development. De Clercq and Shalem (2014) review the landscape of teacher's professional development in Gauteng and identify two important paradigm shifts in the way teacher professional development has been conceptualised. The first period, from the early 2000s until 2009, was characterised by great fragmentation, poor conceptualisation and coordination as most professional development activities were driven by immediate needs of the ever-changing curriculum. De Clercq and Shalem (2014) note that most teacher professional development programmes in South Africa have been instituted as a vehicle through which new educational policies are implemented. The South African education system has seen numerous curriculum reforms since the attainment of freedom that is post-apartheid educational reform policies that saw many curriculum reforms that include OBE of 1998, *National Curriculum Statement* of 2002 and the *Curriculum and Assessment Policy Statement* (CAPS) of 2014. Each curriculum policy needed teachers to undergo some form of training to ensure effective implementation. The department has, thus, used teacher professional development as a platform to train teachers for effective curriculum policy implementation. This training, however, overlooked the enduring challenges linked to teachers' poor content, curricular and pedagogical content knowledge (Fleisch 2008; Welch 2012). There is, thus, a tendency to relegate professional development of teachers until a time when radical curriculum change is needed.

From 2009 to date, teacher development took different forms, content and emphasis, where a more prescriptive approach was assumed with scripted lesson plans and teaching routines. This new approach to teacher learning and development saw the inception of the 2006 Western Cape Literacy and Numeracy Strategy, 2010 Secondary School Intervention Project in Gauteng and the 2011 Gauteng Primary Language and Mathematics Strategy, to name a few, which were focussed on improving teachers' practices to improve learners' results. Again, there were problems in assuming a 'one-size-fits-all' approach which undermined teacher agency and failed to deal with teachers' comprehension of subject knowledge for teaching (Shalem & De Clercq 2019).

The 2007 National Policy Framework for Teacher Education and Development is a policy that targeted the improvement of South African teacher education and development and attempts to provide greater direction, focus and coherence to the field because of the previous fragmented and ad hoc basis on which teacher development interventions occurred. The policy specifies that the Department of Education (DoE) has a pivotal role in supporting systemic teacher development activities while the South African Council of Educators has the responsibility to coordinate, manage, implement as well as quality assure all continuous teacher professional development (CTPD) activities. While these policy developments seemed promising and progressive, little consideration and commitment were given explicitly to developing teachers' intellectual, behavioural and attitudinal well-being, which are central to the life of effective teachers (Evans 2011; De Clercq 2013). The policy imperatives were particularly lacking in distinguishing 'the teacher subject matter knowledge, preferred ways of teaching and curriculum sequencing and pacing which were totally back-grounded' (De Clercq & Shalem 2014:156).

It is also concerning to note that the majority of teacher professional development programmes have been context-independent or off-site where teachers are ferried from their context of practice and assembled at some teacher centre or venue where they attend workshops. These episodic workshops were highly fragmented, did not afford teachers time to learn cumulatively and were far-removed from the classroom which is the teachers' context of practice. As a result, the learning from the workshops was not sustained and the general outcome from such approaches is a disappointing record of poor uptake by teachers (Darling-Hammond et al. 2017, 2020; Dlamini & Mbatha 2018; Gumbo 2020). Although there is adequate evidence indicating that this practice did not result in meaningful teacher learning and engagement, the department has continued to conduct teacher professional development programmes in this manner (De Clercq 2013; De Clercq & Phiri 2013; Maistry 2008; Taylor 2008; Welch 2012).

Against this backdrop, it is evident that TD in South Africa faces many challenges and this says a lot in terms of the fields' state of readiness to develop teachers for the 4IR classroom. Evidently, more needs to be done in re-imaging teacher professional development in the South African context in order to carefully consider the different stages of teacher development as well as teachers' different developmental needs. This is indicative of the need to tailor-make various teacher development programmes to the specific stage in which a teacher is in (Darling-Hammond et al. 2020). The current state of TD illustrates an apparent disjuncture between where TD in South Africa is at and where it needs to be in view of the encroaching 4IR. What this general terrain of teacher professional development in South Africa suggests is that the 4IR and its classroom demands are an added layer of complexity to the already challenged TD system.

Conceptualising teacher professional development in South Africa in the wake of the 4IR

The implications of the 4IR on business and the workplace are widely discussed in the literature (Butler-Adam 2018; Schwab 2016; Xing et al. 2018). A discussion on 4IR implications for education, particularly HE and the considerations of school curriculum reform, is slowly gaining momentum. What is, however, receiving less attention in the literature is how to gear up teacher professional development programmes in order to keep up with the pace of AI and increased digitisation. The discussion of the context of TD in South Africa has illustrated gaps in the conceptualisation and practice of teacher learning through TD. It seems befitting to end this discussion in consideration of the question: what, then, does the advent of the 4IR mean for teacher professional development in South Africa?

In view of the challenges facing the field of teacher professional development, this question deserves immediate attention, especially following the 4IR developments that require quality teachers capable of using sophisticated pedagogies. In response to this question, I suggest two considerations central to the implementation of effective professional development (PD) that respond to the needs of teachers and learners and to the changing contexts in which teaching and learning are, and will be, taking place. Firstly, an acknowledgement and understanding of how the 4IR impacts on TD and, secondly, developing an appreciation of how these contextual 4IR developments will affect the poorest of school districts in South Africa and finally, how TD can navigate these looming challenges.

Taking centre stage in current literature debates are the challenging aspects as well as the potential benefits that come with this digital innovation era. While the 4IR has potential to improve our quality of life as AI brings more efficiency in most facets of life, its benefits are, however, mainly for those who are able to access and consume the digital world (Schwab 2016). In South Africa, the 4IR will most likely highlight and magnify the already existing economic divide/inequalities in the education and schooling system. Spaull (2019) notes with concern how the reproduction of inequalities in the South African education system will continue to play out as access to various educational goods continue to be rationed according to class and race. Teachers are not spared. According to Shalem and Hoadley (2009), teachers in the poorest communities of South Africa struggle accessing both physical and cognitive resources (such as support from parents and the school management and opportunities for teacher learning and growth). These challenges persist and remain an issue of concern and current research (Motala & Carel 2019; Shalem and De Clercq 2019; Taylor 2019) indicates that poor schools seem to have the poorest teacher quality and they remain so because

of lack of access to opportunities for meaningful teacher learning and growth. What this suggests is that when raising the question of access to and embracing digitisation, previously advantaged schools will do so with ease while those previously disadvantaged continue on downwind exclusion.

These unfortunate present-day systemic inequalities will become even more evident where teacher professional development is concerned. Teachers in deprived communities are generally poorly performing because of poor teacher quality and limited access to meaningful teacher professional development. Shalem and De Clercq (2019) posit that teacher professional development programmes have failed to make significant improvements to poor teachers' pedagogical practices. They argue that even attempts such as instructional coaching and scripted lesson plans have not yielded much desired results. Thinking about teacher professional development rising to the 4IR demands becomes worrisome. It is petrifying and, indeed, a daunting task as Menon and Castrillón (2019) make the observation that the South African community is a hybrid mix in which different sectors are transitioning between the second, third and fourth revolutions. This is true in the context of South African teachers where teaching of basic literacy and numeracy still remains a challenge, let alone adopting to 4IR pedagogies. This solicits the question: how will teacher professional development in the South African public schooling context make meaningful developments to poor and deprived teachers in this 4IR era?

Re-imagining teacher professional development in South Africa

Now, the field of teacher professional development (TPD) in South Africa should seriously consider systemic overhaul and acute paradigm shift in terms of how the thinking around and practice of TD are concerned. Oke and Fernandes (2020) argue that success with the 4IR in Africa should begin with an acknowledgement of current education situations in Africa. This suggests the need for a nuanced understanding of what the 4IR entails before applying it to a context. Added to this, an appreciation of where our schools and our teachers are at will relieve some of the 4IR-induced pressures. This essentially means re-defining what effective professional development looks like for our context and realigning that with the redesign of its key purpose, form and content.

According to Duncombe and Amour (2004:141), effective professional development is 'school-based, active, collaborative, progressive and focussed closely on pupils' learning'. This is consistent with Darling-Hammond et al. (2017:v) who suggest that in order for TPD to be effective, it has to adhere to some kind of structured teacher learning programme that specifically targets the enhancement of teacher practices and improvements in student

learning outcomes. The field of TPD in South Africa could easily be in a quandary, considering that it is an already ailing system. What is seriously lacking are clearly defined and structured teacher learning programmes that ensure improved teacher practices translate to successful student learning. Nevertheless, there is an obligation to deliver on teacher learning and professional growth.

One important and necessary shift is the inculcation of the idea of continuous and lifelong learning amongst the majority of South African teachers. It is not enough to attain the teaching qualification, this needs to be coupled with many concerted efforts to ensure that continuous learning is prioritised. Beairsto and Ruohotie (2003) argue that teachers need to be able to retain and expand their competence over the course of their career. Continuous teacher learning and growth is a necessity that South Africa cannot afford to compromise on. Lamprini and Bröchler (2018) rightly argue that education needs to be at the helm of the transformation agenda and one obvious way to ensure this is capacitating teachers with the appropriate and advanced skills needed for transformation in the delivery of educational goods. In agreement with this view, Dhaliwal (2015) proposes that teachers should consider themselves as lifelong learners as the nature of the new knowledge economy requires them to be actively involved in an iterative process of learning, unlearning and re-learning in order to keep abreast with the fast-changing world. This is, especially, necessary given the 4IR age where information is easily available and all things to do with the mediation of teaching and learning are constantly undergoing major changes. In the field of TPD, this kind of learning has been coined CTPD and refers to programmes that are put in place for practising teachers to help them keep abreast with the ever-changing education environment (Darling-Hammond 2006; Feiman-Nemser 2001; Fullan 2002).

It is important to note that notable changes in education are mostly characterised by curriculum reform and South Africa has seen a number of these in the post-apartheid educational reform programmes. As a result, TPD has been largely conceived as a vehicle through which new curriculum policy is introduced which has, unfortunately, undermined the true purpose and value of CTPD (Fleisch 2008; De Clercq 2010; De Clercq & Shalem 2014; Welch 2012). Thus, adopting the lifelong learning approach into the TPD framework is an immediate imperative in South Africa. Embracing the principles of lifelong learning can instil creativity, agency and responsiveness in teachers that enables them to be adaptable to new contexts of practice such as that presented by the 4IR. Dhaliwal (2015) defines this as growth learning where teachers are positioned to the acquisition of knowledge and skills that they did not have before that enables them to do what they could not do before. In other words, this kind of learning enables teachers to be self-directed in learning and adapting to new scenarios. This will see the development and

enactment of continuous teacher learning programmes and forums that are not limited to curriculum policy reforms but ones that allow teachers to constantly reconstruct their knowledge and skills.

Teaching is a knowledge-based profession and, as is well recorded in the literature, many TPD programmes and activities generally focus specifically on the different kinds of knowledge essential for professional practice (Darling-Hammond 2006; Feiman-Nemser 2001; Fullan 2002). This has seen the adoption of a range of initiatives varying in form and content. According to Kennedy (2005), there is a wide spectrum of TPD models depending on the circumstances under which the different models are adopted as well as the form(s) of knowledge they foreground. Teacher development in South Africa, for example, has seen many turns with the view to improve teacher performance. Popular amongst the many adopted in South Africa has been the training model which is off-site and conducted by 'experts' from the DoE. This type of model has been largely criticised for its lack of connection to the classroom context reality and its failure to recognise teachers' input as it generally perceives them as blank slates or passive receivers of knowledge (Kennedy 2005).

The organisational form of teacher learning programmes and activities is, thus, a critical dimension of TPD in South Africa that needs re-imagination. While they are effective in the dissemination of information, context-removed TPD activities have been seriously critiqued for failing to prioritise the knowledge areas teachers needed for effective professional practice and failing to situate knowledge in the context of practice (Christie et al. 2005; De Clercq & Phiri 2013; De Clercq & Shalem 2014). There is an obvious bias in the literature for school-based TPD activities as they are argued to be highly effective in facilitating the development of what Cochran-Smith and Lytle (1999) call 'knowledge-in-practice' where most essential knowledge for teaching or practical knowledge is embedded in practice and the opportunities to reflect on practice are plentiful. Job-embedded professional development offers opportunities for classroom observations, modelling of instruction, discussions on specific teacher practice scenarios as well as practical engagement and reflection on the available teaching and learning materials. Desimone (2009) propounds that teacher development is complex, dynamic and highly embedded in teachers' daily lives; hence it is more important to focus on the critical features of teacher's learning that impact on their professional practice. As such, TPD activities ought to be situated within the context of practice so that teachers can immediately enact ideas from the programme or activities. Such an approach is ideal in the wake of the 4IR where the classroom and the school context can both be the vehicle and the testbed for introducing and experimenting with new concepts and ideas as suggested by Lamprini and Bröchler (2018).

While the organisational form of TPD programmes and activities is an important consideration, this discussion is incomplete without contemplating on the content/teaching foci of those very programmes. The teaching foci, according to De Clercq and Shalem (2014), pay attention to the key or focus content areas in professional development programmatic activities. The core PD activities have to be aligned with the educational needs of the 21st-century learner. Hussin (2018:94) identifies three main groups that characterise crucial proficiencies for education in the 21st century, namely, Foundational Literacies, which deal with how students apply core skills to everyday tasks, Competencies, which deal with how students approach complex challenges and Character Qualities, which deal with how students approach their changing environment. These proficiencies require teachers to be able to ensure that learners develop, among many others, complex problem-solving, critical thinking, creativity, people management, emotional intelligence and cognitive flexibility skills (Hussin 2018; Schwab 2016). Darling-Hammond et al. (2017) argue that these skills have to be developed within disciplines and specific content/subject areas. In other words, teachers' PD will be structured in such a way that teachers are guided on how to explore and develop these generic skills within a specific learning area. They (Darling-Hammond et al. 2017) argue that this is the most effective PD as it:

> [*C*]an provide teachers the opportunity to study their students' work, test out new curriculum with their students or study a particular element of pedagogy or student learning in the content area. (p. 5)

It is also important to point out that teachers also need to be equipped with knowledge and skills related to the digital tools that characterise the 4IR to be able to meet the learning preferences and needs of the digitally literate current and future learners. Oke and Fernandes (2020), however, highlight that there seems to be little clarity on the idea of the 4IR and people generally take it to mean technological advancements. While associating 4IR with digitisation is accurate, it is limited to think that it ends with the technological advancements; it actually means much more. Butler-Adam (2018) notes that this digital era needs to be interpreted along with other social and communication skills. For pedagogy, the 4IR demands that teachers understand the interface between their classroom practices and the 4IR that is determining the context of their practice. This means that TD has to focus on developing in teachers pedagogical competencies that foster 'deep mastery of challenging content, critical thinking, complex problem-solving, effective communication and collaboration and self-direction' (Darling-Hammond et al. 2017:1). Re-imagining TPD incorporating these crucial skills will go a long way in preparing South African learners for the future. In other words, TD can equip teachers with some relevant skills for the 21st-century learner independently of technology or digitisation of the classroom.

Conclusion

This chapter was primarily concerned with illuminating, both the challenging implications and growth possibilities the 4IR imposes on the field of TPD in South Africa. It seems, from the above discussion, that the challenges are overwhelming and will persist and hang over us like a dark cloud for the next few decades. The reality is that the South African TPD context is still a cause for concern given poor teacher take-up, poor teaching quality and poor learner performance. There is an apparent disjuncture between TPD and what the teacher has to deliver in the classroom. These persistent challenges are exacerbated by the advent of the 4IR which is fast changing the context of teaching and learning, and the present-day teacher in South Africa is ill prepared and incapacitated to provide the future workforce with quality and relevant education. The advent of the 4IR is certainly demanding a different way of professionally developing teachers to ensure teachers are empowered with 4IR-appropriate pedagogies.

Despite the gravity of the challenges, it is of paramount importance to begin charting ways through which teachers can be equipped and professionally developed so that they learn and grow alongside the innovative advancements in the context within which they operate. It is, thus, time to reimagine the programmes and practices of TPD in the South African public schooling context so that pedagogical constructs are developed progressively to meet 4IR classroom demands. This chapter has established the fact that deliberate efforts are required to ensure that education remains in a position of leading, feeding and supporting future generations with the right and high skills for the 4IR. The efforts that will change the practice of TPD in South Africa include reskilling and re-educating teachers through restructuring and refocussing the field of TPD to align with the 4IR demands. In particular, this calls for a whole paradigm shift in terms of how TPD is conceptualised and practiced. The organisational form has to learn more towards context-embedded programmes and activities that speak to teachers' everyday school and classroom experiences. More concerted efforts also have to be directed to ensuring that the content/teaching foci of the said PD activities reflect knowledge and skills relevant for the 21st-century learner. Different stakeholders, therefore, need to reflect on how the structures and practices of TPD need to adapt and prepare teachers for the current and future classroom with the focus of advancing knowledge and practice of effective TPD to be more responsive to the inevitable changes imposed by the 4IR.

Chapter 7

Pre-service teachers' technological literacy: How ready are teacher education programmes for the 4IR?

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Abstract

South African education has evolved towards integrating technology into classroom practice in order to promote learner achievement. Incorporating technology into the classroom requires that teachers change their classroom practice. The current policy mandates in South Africa promote that teachers incorporate technology into the classroom. However, current research in South Africa suggests that in-service teachers are seldom incorporating technology into their classroom practice appropriately, and similarly, pre-service teachers in training tend to struggle to do so. The study uses a mixed-method approach, incorporating a survey, the *Technological Profile Inventory* (TPI), to determine pre-service teachers' conception of technology (*Nature of Technology*). This study investigates 200 final year pre-service students' levels of technological literacy, guided by the Mitcham's framework of focussing on how the pre-service teachers 'think' about technology and further probes the

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case of a female pre-service teacher who has a basic level of technological literacy. The results suggest that in general, the pre-service teachers have a basic level of technological literacy and therefore might struggle to integrate innovations using technology into their classroom practice.

Introduction

Internationally, policy and practice support transformative technologies in pedagogy (Brevik et al. 2019; UNESCO 2018). The policy imperatives in South Africa also support the transformation of teaching and learning in classrooms through ICT. The White Paper on e-Education (DoE 2004) outlined the elements of the transformed classroom. This policy was supported by others, for example, the publication of Guidelines for Teacher Training and Professional Development in ICT (DBE 2007), which provided guidelines for TPD in ICT and educator competencies within a developmental framework. Furthermore, the Professional Development Framework for Digital Learning (DBE 2007; DoE 2018) provides an approach to the professional development of teachers and supports improved learning outcomes and higher learner attainment in the curriculum. Moreover, Goal 16 of the DBE Action Plan to 2019 (DBE 2015) supports strategies to improve the professionalism, teaching skills, subject knowledge and computer literacy of teachers throughout their careers. These policies support the Integrated Strategic Planning Framework for Teacher Education and Development (ISPFTED) (DBE 2011), which commits us to investing in digital technologies to support the delivery of the strategy supporting teacher professional digital development (DoE 2018).

The policies support the need for more transformative pedagogies (more learner-centred, with knowledge-building and higher-order thinking skills) to magnify the range of opportunities offered by digital tools and resources to support and have an impact on learning (Blundell et al. 2020; McKnight et al. 2016; Ng'ambi 2013). These opportunities were not available to the majority of learners during the apartheid years (Kallaway 1984, 2021) and are still not readily available post-apartheid within the technological realm (Torres & Giddie 2020). Teachers are pivotal to realising the benefits of the transformative pedagogies because an effective blend of pedagogies and interactions that are supported by digital tools and resources may lead to deep learning (Carter, Maree & Shakwa 2019; Keane et al. 2016, Mishra 2019). Past South African national assessments show that learners need to develop skills for deep learning (DBE 2008, 2017; Howie et al. 2008, 2017). How digital tools and resources are used in the learning environment will depend on the pre-service or in-service teachers' analysis of the accessible resources, the learners and their various contexts, and teachers' individual evaluation of their digital learning competencies; developing digital learning competencies is the responsibility of role players at all levels of the system

(Blundell et al. 2020). While these policies allude to *why* a professional teacher or a pre-service teacher must be ICT competent, what is missing is the *how*, particularly in variable contexts, this should be enacted. Specifically, this gap is glaring for higher education institutions (HEIs) who train pre-service teachers in teacher education programmes. The HEIs are not given directives on how these should be enacted. Similarly, within the *Minimum Requirements for Teacher Education Qualifications* (MRTEQ) (DHET 2015), no clear guidelines show pre-service teachers what it means to be digitally (or ICT) competent; neither does the policy contextualise the process. Every HEI interprets the policies differently and places variable expectations on pre-service teachers who come from variable contexts and teach in different contexts. The one-size-fits-all approach of policy ignores the pre-service teachers' role in the ICT integration process and their unique contribution to the ICT integration process.

This study was conducted in one of the wealthier provinces in South Africa, at a single HEI in the Western Cape Province. Pre-service teachers who enter the HEI range from those who come from schools that were highly resourced to the majority from under-resourced schools, with no running water or electricity and an acute shortage of classrooms. These pre-service teachers' own teachers were often poorly qualified; many struggled with subject matter, and it is likely that these teachers seldom incorporated technology into their teaching. Amidst these variable conditions, teachers are expected to integrate technology into their classroom practice. For instance, the Western Cape Education Department [WCED] (2012, 2017) policies are guided by the national policy imperatives. Nevertheless, current research in South Africa suggests that in-service teachers are seldom incorporating technology into their classroom practice appropriately (Hennessy, Harrison & Wamakote 2010; Spaull 2013; Vhurumuku & Chikochi 2017). Similarly, pre-service teachers tend to struggle too, even though they are classified as millennials, which implies that they should have the confidence to integrate technology into their practice. Consequently, this area requires research to fill the gap in knowledge. Thus, this study monitors a group of pre-service teachers' technological literacy and further probes how a selected case study perceives the integration of technology into classroom practice and whether the background of the pre-service teacher influences classroom practice.

Problem statement and overall argument

The South African government supports that teachers integrate technology into classroom pedagogy and practice. Policy prescribes that teachers must teach with technology and that pre-service teachers must be trained to do so as well. While more ideological knowledge exists around teachers', especially pre-service teachers', technology integration into classroom

practice in South Africa, few empirical studies illuminate the pre-service teachers' experiences of the integration of ICT into classroom practice at schools. Notwithstanding, the policies claim to create an infrastructurally conducive environment at schools and imply that learners are technologically receptive to ICT integration yet tend to overlook the pre-service teachers as unique human contributors to the process, who are shaped by their own personal backgrounds that are influenced by their technological literacy. Therefore, this study seeks to explore pre-service teachers' levels of technological literacy in their final year of study.

Objectives

1. To determine the profile of a group of pre-service teachers' levels of technological literacy in one HEI in the Western Cape Province, South Africa.
2. To investigate whether the pre-service teachers' level of technological literacy is influenced by how they conceive of technology.
3. To investigate whether there is congruence between the pre-service teachers' technological literacy in terms of (a) their socio-economic status (SES) and (b) conception of technology.

Research questions

1. To what extent are a sample of final year pre-service student teachers technologically literate?
2. How does their conception of technology influence their technological pedagogical choices in the classroom?

Literature review

Education has evolved towards learner-centredness, and the construction of knowledge is developed within a classroom learning environment promoting learner collaboration and interaction (Blundell et al. 2020; Brevik et al. 2019; McKnight et al. 2016). This kind of learning environment is promoted through integrating technology into classroom practice. Integrating technology into the classroom learning environment has been shown to promote learner engagement internationally, for instance, in China (Chui, Mak & Li 2013; Lu & Price 2018). The success of these and other countries in integrating technology in the form of ICT in their education system is likely to have an impact on informing developing countries like South Africa to improve classroom practice, where there have been serious problems with learner achievement at various levels in the education system (Howie et al. 2008, 2017; Spaull 2013).

Evidence shows that the past pedagogies have been ineffective in promoting student learning amongst South African learners (Hennessy et al. 2010). Given that current learners are classified as millennials, where millennials use technology at higher rates than people from other generations (Junco & Mastrodicasa 2007), technology should be incorporated into South African learners' education to engage them in the learning process.

Currently, much literature shows the use of technology in the classroom as a change agent has been addressed in classroom practice (Blundell et al. 2020; Brevik et al. 2019; Chui et al. 2013; N'gambi 2013). However, there is a lack of literature on how pre-service teachers are navigating the implementation of technology into their own practice given that the majority of them in the South African context have not modelled this throughout their own schooling. Thus, this study monitors the technological literacy amongst a group of pre-service teachers and the impact that their past histories would have on their uptake of technology prescribed by the government and the HEI in the Western Cape Province.

The concept of technology

Technology is a contextual phenomenon, guided by communities' activities and culture (Feenberg 1999). Technology is the manipulation and modification of the natural and/or man-made environment and is a process that uses practical ways to produce an end-product that meets and satisfies human needs and comforts (Schatzberg 2018). Many people perceive technology as an end-product, namely, an artefact. They omit to see technology as knowledge and processes that create artefacts. Technological artefacts have two natures, namely, physical (size, shape and look) and functional (requires a function, which the designer intended). A technological artefact is constructed in such a way that the physical properties allow function to be realised (Mitcham 1994). Design is a multifaceted process by incorporating six modes, namely, scientific knowledge, technical, market, political, juridical and aesthetic, to produce an artefact (Dakers 2006). Hence, the development from an idea to an artefact requires a process informed by decisions at many levels.

The nature of technology and how we conceive of technology can be categorised by four main theories, namely, instrumentalism, determinism, substantives and critical theory of technology (Dakers 2006). Instrumentalists and determinists posit that technology is controllable, which implies that it is value-free, while substantives and critical theorists claim that there are values embodied in the use of technology – value-laden – but both question the role of humans in the choices made when using a technology. The critical theorists claim that the values should be decided collaboratively and democratically; the greater the human participation, the better the outcome.

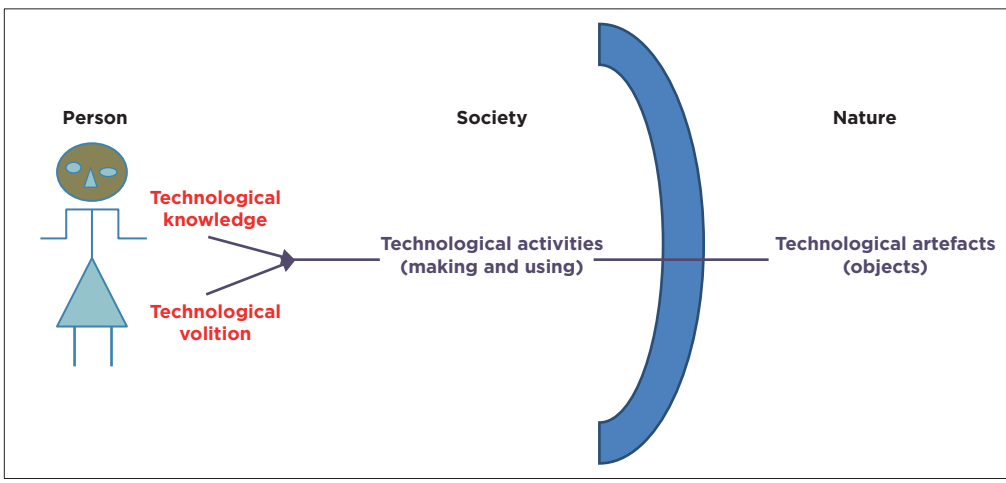
Mitcham identified ways of conceptualising technology (Figure 7.1): objects, knowledge, activities and volition (Mitcham 1978), which shape technological literacy:

1. Objects – we regard technology as a set of objects that are the results of design and making. We speak of 'technical objects' when the objects are a result of the technological activity.
2. Technology as knowledge refers to a discipline with a distinct type of knowledge.
3. Technology as processes deals with designing, making and using the main type of technology.
4. Technology as volition refers to the notion that technology is part of our human will and therefore intrinsic of our culture and relates to human values.

Mitcham further claimed that one could conceive of technology at different levels, from simple to sophisticated. Collier-Reed (2006) developed levels of technological literacy shown in Table 7.1.

The key ways of conceptualising technology all interact with one another. The way that a person engages with technology is often a combination of the person and society that influences the nature of technology, which affects the individuals' conception of technology. Consequently, these interacting variables shape one's technological literacy.

The intertwined nature of technology with our lives is embedded in, rather than at, the peripherals of our lives. Quality of existence is intertwined with technology. The intertwined nature of technologies and our lives is reflected



Source: Adapted from Mitcham (1978:234, 1994:160).

FIGURE 7.1: Schematic description of the nature of technology.

TABLE 7.1: Categories of technological literacy.

Nature of technology (conception)	Categories
Simple	Artefact
	Application of artefacts
	Process of artefact progression
Advanced	Using knowledge and skills to develop artefacts
	The solution to a problem

Source: Adapted from Collier-Reed (2006).

in our political systems and orders (Dakers 2006). Technology can be an enabler or a disabler of democracy, and this populist view denies choice, and without choice, the dominant paradigm will progress. The concept of volition, as design or intention, is part of the conception of technology; yet, if there is a lack of choice, it will limit volition, hence the will to want to use the technology. It would prevent the human from developing with the technology, so that the human becomes an agent that buys into the idea, accepts the technology and works with the technology to become a human emerging with technology.

Technologies can be classified in two ways, namely, mundane and exotic technologies. Lay people respond to these technologies in different ways. Mundane technologies are more or less invisible – we co-habit with them in our everyday lives, for instance, shoes, Velcro and pencils. We are familiar with the technologies and seldom question their ethics. On the contrary, exotic technologies, that is, the emergence of novel technologies, are embroiled in 'public understandings' (Dakers 2006), for instance, genetic modifications and nanotechnologies, and lay people respond to these with sceptism. Thus, lay people might feel that they are not involved in the technological process and that the artefact produced is not developed in their own societal interest, but in the interest of others.

This interpretation of 'othering' could have an impact on the choice of using the technology. Such a choice might have a political impact. This can apply to the choice of using technologies such as ICT in the classroom. Many policies, both internationally and nationally, have been endorsed, and they supported the Fourth Industrial Revolution (4IR) student achievement and alleviated inequality. The 4IR is a systematic change that has forced all sectors to experience a disruption in their existing structure (Tsakeni 2021). This is a fundamental force that exceeds human strength with the pressure of automation characterised by technology for the progress of humanity (Xu, David & Kim 2018). The 4IR is a vital movement in the development of technology that interrupts existing industrial structures.

Policy in teacher education prescribes that pre-service teachers integrate ICT into classroom practice (DHET 2015) driven by the pressures or ideals defined by the discursive environment of 4IR and is accepted that ICT would

find a way into schools and universities. However, ideological knowledge informs the 4IR debate with policy supporting that if all technology infrastructure and technologically receptive learners fill classrooms, then the pre-service teacher can walk into a classroom and teach with technology. The policy assumes that if the pre-service teacher enters the classroom with knowledge shaped by their school, undergraduate and their university teacher education programmes, then they would be ready to teach with innovative pedagogy. Moreover, the policies are shaped by sparse empirical evidence and prescribed without contextualising, disregarding the influence of their own social experiences and backgrounds. Notwithstanding, the social shaping of technology (SST) (Mackenzie & Wajcman 1985) broadens the technology policy agenda. Traditional approaches examine the outcomes or 'impacts' of technology change – this work examines the content of technology and processes involved in innovation. A variety of scholars with differing concerns and intellectual traditions find a meeting point in the SST project, united by the insistence that the 'black box' of technology must be opened to allow SES patterns embedded in both the content of technologies and the processes of innovation to be analysed (eds. Bijker, Hughes & Pinch 1987; MacKenzie & Wajcman 1985).

Technological learning and the teaching approach

A teacher should develop lesson plans to ensure that the learner would develop meaningful learning. Teachers' conception of technology is likely to influence how they would interact with technology. If a teachers' conception of technology is that of an artefact, it is very likely that they have a simplistic understanding of technology, which implies that they would use the technology very simplistically. It is likely that this teacher would take the technology and use it as a replacement with very little meaning to the learning process. For instance, the teacher could 'use' technology as a replacement tool. They could use a Smartboard in the same way as they would use the whiteboard, which would give very little meaning to the use of the technology, as the Smartboard can be used in a more interactive way to promote meaningful learning amongst the learners. On the contrary, if the teacher teaches with technology where they 'do' technology, which is the focus on the use of the technology in the pedagogical process, then they would understand that the use of technology is more sophisticated within the pedagogical process.

If a teacher is classified as one that 'uses' technology and takes on a more simplistic approach to the use of the technology, then one might argue that the teacher is unlikely to incorporate the use of the technology in the pedagogical process and would therefore limit meaningful learning for the learner. The limitation would let them disengage with the context, and thus, they are unlikely to consider the teaching context and adjust the use of the technology to the context. On the contrary, if a teacher has a more sophisticated

conception of technology, then they are likely to 'do' technology. These teachers might incorporate technology into the pedagogical process more meaningfully, which implies that during the pedagogical process, they would be able to consider contextual variables in their teaching and adjust these according to the needs of the learners in order to promote meaningful learning.

Given the complexity of the technological process and its multifaceted nature, it could be that pre-service teachers, although classified as digital natives, are more likely to engage with the mundane technologies like a smartphone and use it for social media and be less receptive to the exotic technologies like sophisticated ICT tools in the classroom. Perhaps this decision is driven by the way the community perceives the technology and the impact of the years of education on their technological literacy.

Hence, this study explores how pre-service teachers conceive technology and the impact of this conception on their classroom practice.

Methodology

Sample

The sample for the quantitative data collection included 200 final year pre-service teachers who completed a degree programme and entered the one-year PGCE at a HEI, previously classified as a disadvantaged university in the Western Cape Province, South Africa. Data were collected during their Education Practice course, which all students have to attend because it is a core course.

Combining qualitative and quantitative research methods

Although the study reported in this chapter is largely qualitative, it has included important selected quantitative information gathering strategies as recommended by Field (2005). The data collection, analysis and reporting were in line with issues of confidentiality, anonymity, and the right to withdraw ethical considerations, guided by the institution studied.

Quantitative data collection

Quantitative data were collected using a questionnaire, the TPI, a reliable and valid instrument (Luckay & Collier-Reed 2014). The questionnaire was administered to the pre-service teachers during a 1-h lecture period at the university. Profiles of pre-service teachers' levels of technological literacy were developed in two main categories, namely, in the category 'Nature of Technology' – how pre-service teachers conceive of technology – (under the dimensions *Artefact*, *Process*); and

in the category 'Interaction with Technology' – how pre-service teachers interact with technology – under the dimensions *Direction*, *Instruction*, *Engaging* and *Tinkering*.

Qualitative data collection

Qualitative data interviews (Bailey & Bailey 2017) took place with a single pre-service teacher as a case – profiled to represent an average pre-service teacher in the class – a female with a BA degree in the age range 21–23 years. The qualitative data analysis of a single pre-service teacher was classified as 'average' based on the results of the questionnaire, the TPI, which the pre-service teacher in the sample cohort completed. Observations were recorded in field notes and on video camera at the school where the pre-service teacher conducted teaching practice. At the end of each classroom observation, interviews were held with the pre-service teacher to discuss her perceptions of the lesson and the reasons for particular actions. Themes were produced and the analysis of patterns and generation of themes would give insight into the qualitative data (Patton 2005). Document analysis included the pre-service teachers' portfolio of information, marks achieved for the course and reflective journal pieces while on teaching practice.

These data provided richer insights into the technology classroom learning environments created by the educators at the school. Interviewing the pre-service teacher about her learning environment has the potential to provide very useful information to other educators, as they attempt to understand the preferences of their learners, and this can put them in a better position to interact with them meaningfully.

Findings

Data collected from 200 pre-service teachers were used to find the levels of technological literacy amongst the groups of pre-service teachers studying towards a variety of subject areas. Profiles of students' scores on the dimensions such as *Artefact*, *Process*, *Direction*, *Instruction*, *Engaging* and *Tinkering* were generated. The average scores based on the scores of the pre-service teachers' responses on the Likert scale from 1–7 were generated for the group as a whole. Overall, an average pre-service teacher in the sample could be considered to have a reasonable level of technological literacy based on the dimensions in the TPI (Table 7.2). In the category 'Nature of Technology', there were a significant number of pre-service teachers who conceived of technology as an artefact, a less sophisticated conception of technology. The higher levels of agreement in conceiving technology as a *Process* rather than an *Artefact* suggest that these pre-service teachers entered their first-year university programme with at least a basic level of technological literacy,

TABLE 7.2: Average item mean of final year pre-service teachers in a teacher education programme.

Technology	Dimension	Average item mean	
		Group (*n* = 200)	Case student (*n* = 1)
Nature of technology	Artefact	3.3	5.6
	Process	5.0	5.5
Interaction with technology	Direction/instruction	3.4	3.1
	Tinkering	4.4	4.0
	Engagement	5.4	5.2

albeit a level higher than that of an artefact. The results suggest that pre-service teachers typically have a reasonable level of technological literacy when they arrive at university – which suggests that the pre-service teachers are managing to fulfil the requirements in the national curriculum in addressing technology education. The results also indicate that there is a difference in levels of technological literacy by gender, age and SES background.

Of the 200 students, 70% of the pre-service teachers in this sample were female and 30% was male. More than half of the pre-service teachers' ages ranged between 21–23 years (55%), and 45% ranged in age from 24–47 years. Most pre-service teachers had completed an Arts degree. Qualitative data were collected through interviews and document analysis from one pre-service teacher classified as average, namely, a female with a BA degree in the age range 21–23 years within this sample cohort.

The qualitative data analysis of a single pre-service teacher was classified as 'average' based on the results of the questionnaire, the TPI, which the pre-service teacher in the sample cohort completed. The results guided by the responses on the questionnaire and the interviews suggest that the pre-service teachers' technological literacy and the ability to integrate technology in classroom practice are influenced by the following themes, namely, the students' SES status and background (growing up, parents' influence and school influence); teacher training experiences (lectures, university and environment) and practical teacher training at school placements (influence of the schools, learners and teachers). These experiences influence the pre-service teachers' practices at schools and influence the pre-services teachers' perceptions and the ability to influence their levels of technological literacy and hence influence how likely it is that they would integrate technology into their classroom practice. The data were triangulated against the document analysis and the classroom observation field notes and codes.

Discussion

The quantitative evidence suggests that the technological literacy of a group of PGCE pre-service teachers at a HEI in the Western Cape province was

reasonable, based on the concept the *Nature of Technology* ('how one thinks about technology') and the *Interaction with Technology* ('interaction with technology'). The focus of this study would only be on the former. It is evident that the group of pre-service teachers, although they are classified as digital natives, might have a stronger tendency to use technology in a more simplistic form, very likely as a means to access social media, read material, access knowledge and do research (Collier-Reed 2006). Thus, it is evident from the quantitative data that their levels of technological literacy can be considered reasonably basic, which means that the pre-service teachers in the PGCE group perceived technology as an *Artefact*.

In order to interrogate this finding and gain insight into why this is so, a pre-service teacher, identified from the cohort as a 'typical' participant, based on the results of the completed TPI questionnaire in the quantitative part of the study, after analysing the questionnaire, was considered to display all the key characteristics of the PGCE group. Consequently, this participant was chosen as a case, with the following key characteristics to represent the group, namely, a female with a BA degree in the age range 21–23 years.

The study investigates the pre-service teachers' levels of technological literacy, and the case of a single student was explored through interviews, observations and document analysis. The key findings from the interview responses of the pre-service teacher are discussed. The interviews were slightly paraphrased to avoid inconsequential statements. The meaningful segments from the transcribed texts were finally coded and arranged into categories of themes and sub-themes as presented below:

- **Theme 1:** SES status and background (growing up, parents' influence, school influence):
  - Three sub-themes were identified, namely, Sub-theme 1a: Awareness level/interest; Sub-theme 1b: Exposure; and Sub-theme 1c: Family background.
- **Theme 2:** Environmental and educational factors:
  - Three sub-themes were identified, namely, Sub-theme 2a: Interest/motivation; Sub-theme 2b: Peer group/school location; and Sub-theme 2c: Value of technology.

Theme 1: Socio-economic status and background (Growing up, parents' influence and school influence)

The case student grew up with her family, mother, father and sister in a township in the Western Cape province. She claimed that she lived in a 'better part' of the area and would refer to other people within a part of the township she lived in as 'underprivileged'. She was the first person in her immediate and

extended family to obtain an undergraduate BA degree and was also the first to pursue a PGCE. When she grew up, the family possessed one family television, and she did not have a smartphone or computer until she was at high school and university, respectively. She claimed that she was discouraged from having a smartphone because it was not safe to have one in the area where she lived, as it was likely to be stolen by gang members in the area. Thus, her parents suggested that she refrain from owning one, which resulted in a lack of interest in owning any form of technology throughout high school. However, when she started university, she was under pressure to complete assignments and would use the laptop computer that her father bought her in order to complete her university work. Her parents would support her with anything she needed to complete her studies.

From the interview as seen in the minor categories, the socio-economic factor of the parents influenced the student level of awareness and understanding of technology. The participant was seldom exposed to simple technology such as television at the early stage of her life. The evidence suggests that the participant is likely to have a shallow level of technology literacy owing to the family background that affected her level of exposure. *'*I still grew up where we played outside so I didn't use technology'.

The background influence on the student's use of technology was evident in the following statement, 'Technology did not feature prominently in my lifestyle and was first used at university for assignments'. It was evident that the student's childhood experiences shaped her use of technology in later years and influenced her simplistic conceptions and interactions with technology as an adult. Exposure deals with one level of perception, the perception of technology is just to play games on a phone, as stated in her interview:

> 'No, I got my first phone in Grade 8 or something like that, but we had like these normal like games educom [*?*] and those types of games but it wasn't like technology.' (Case, 23-year-old female pre-service teacher, date unspecified)

Much value was not given to technology because her interest was not there:

> 'Yes my interest is not in technology, we just ran [...] ball ran up and down hide and seek that type of [...] we weren't like building things taking things apart and [...].' (Case, 23-year-old female pre-service teacher, date unspecified)

It is less important in her life as seen from this statement. She was not exposed to technology devices which might have ignited her knowledge of technology. She confirmed her lack of interest of technology extended to not watching television: 'Like I said I didn't watch TV a lot, I was one that played outside'. In conclusion, the SES influenced her technology literacy.

Thus, it is evident that the student's background played an important role in her conception of technology, as her thinking suggested that technology was not a 'must have' in her life and that she could do without it, which is likely

to influence her use of technological tools in the classroom. Furthermore, her interaction with the technological tools is likely to be based on the fact that her parents made her believe that owning such a tool would possibly be a safety hazard, especially in the community where she lived. She did not grow up with technological tools and thus had very little time to engage with them, unless it was out of necessity – like when at university for assignments to be completed. Evidently, the theory of Mitcham (1994) is supported, as the influence of the technological activities of the society influences the technological use. The use of the technology was not evident in the community that she grew up in. Policy, on the contrary, as suggested by McKenzie and Wajcman (1999), posits that the 'black box' of technology must be opened to allow SES patterns embedded in both the content of technologies and the processes of innovation to be analysed. Consequently, the influence of the value that the student placed on the use of technology is likely to affect their classroom practice.

Theme 2: Educational factors (Teacher training experiences [lectures, university, environment])

The student's family valued education and her parents supported her in her educational endeavours. She attended an ex-Model C school in the nearby affluent area. During her schooling, she claimed that she was exposed to technology in the classroom. She claimed that the teachers at school in both primary and high school used technology as a projector '[…] to copy notes […], watch videos […] of books read […]'. The student was not in any way stimulated to develop the drive or desire for technology as stated: 'At Parrow High, we didn't use technology'. The location of the school made it difficult to integrate with other people or make use of computer devices:

> 'Not only at school but at home, I would write out assignments and I would go to the library because at that time I used books I didn't use Internet.' (Case, 23-year-old female pre-service teacher, date unspecified)

The student was not encouraged, which made her have very low morale in the knowledge of technology. Although the project was used to watch movies in the school, the significance was not noticed: *No technology, not that I can remember was not used, we would use the projectors or watch a movie that was the only technology that I can think of.* She never observed the teacher model technology in any other way or be creative with the technological tools that they had access to at the school. Thus, overall, she felt that her schooling re-enforced her childhood ideas and conceptions of technology – that it was not necessary and added limited value to the educational experience.

Besides, the environmental factor also determined how friends associated with technology. The influence of peers within the location of the school is similar to the condition of the school (Brevik et al. 2020). The peers were also

too underprivileged to enjoy technological facilities which might have increased their knowledge of technology. Many of the peers were not used to technology, and subsequently, the usage of technology was not of any significant value as stated in the interview: 'Because we all were not like underprivileged, but we just didn't have that advantage to have like technology things and stuff like that'. It is obvious from the evidence that the participant never understood the impact of the lack of technology-based equipment on her conception of technology, as seen from the dialogue: 'I prefer paper than the laptops just because I don't know, I just don't know. So you didn't see any value in using technology? That's why I don't think it is really'. She then carried these conceptions into her university studies.

At university, she claimed that she was exposed to technology during her teaching practice and in some of the subject method classes. However, she claimed that, 'I am not a tech person and find it difficult to integrate it [technology] in methods'. Sometimes, she would feel anxious to do so. Her only impetus to integrate technology into her teaching was if the lecturer required her to do so. She further claimed that she would 'only use MS PowerPoint and Google Translate' as she used the tools to support her language lessons. Evidently, during the lectures, it was evident that her conceptions and interactions with technology changed minimally, and she only used technology if pushed to do so, and it was a requirement of the module – a factor influencing pre-service teachers (Batane & Ngwako 2017; Kola 2019).

During her practice teaching at schools, she felt that the Grade 8 class that she was teaching should be monitored more with their technology use as '[...] cannot control the class as they go onto other sites'. At the school, which practised regular use of technology, in classroom practice, she believed that learners should write more: 'I will prefer that they write, because they cannot write' and further '[...] even the learners in the poor school could write better'. This supported her worldview of the use of technology, namely, that 'learners and teachers do not have to use technology all the time'.

Generally, from the interview session, recognising the lack of technology literacy in pre-service teacher indicates that most of these students have a mixed feeling about technology usage. Some students' perception of technology is for personal gratification and social interaction. Their perspective on the integration of technology is only based on chatting and sending emails. Therefore, the conceptual understanding is limited.

Conclusion

Many policy imperatives follow ideological evidence to support its implementation strategies. However, the policy focus on infrastructural and learner readiness for technology integration does not support pre-service

teachers to integrate technology into their classroom practice. The students themselves have key background knowledges that are shaped at various stages in their lives; this defines their technological literacy and hence their classroom practice. The glaring gaps in current policy, with a lack of focus on the person – humanistic, social and contextual issues, are unlikely to support pre-service teachers in their journey towards technological integration as professional teachers. Therefore, these have implications for national policy, university policy and school teaching practice support, with all being unlikely to be fully supportive and thus be ready to prepare pre-service teachers for the 4IR at schools.

Chapter 8

Transforming teacher preparation for science practical work in the context of 4IR through computational thinking

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Abstract

Computational thinking is a skill inherent to 4IR environments and the 21st century. Amidst calls to reimagine digital and computer technologies-based computational thinking as a basic skill for citizens, questions are raised on how the skills can be integrated into current school curricula. Further questions arise on how teacher training programmes prepare pre-service teachers to integrate computational thinking in their future classrooms. In this study, I explored the preparation of pre-service teachers to facilitate digital and computer technologies-based computational thinking through science practical work and its influence on how they conducted instructional design for practical work. The ADDIE model was used to guide the pre-service teachers as they engaged in learning activities to integrate computational

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thinking and practical work in classroom practice. I purposely selected the case of a pre-service science teacher preparation at one South African university which had embedded computational thinking in the methods course. In this qualitative, longitudinal and explorative single case study, data were collected by means of reflections generated through group work by 25 pre-service teachers as they engaged in an instructional design process of computational thinking integrated practical work. In addition to guiding the instructional design process that the pre-service teachers engaged in, the ADDIE model guided also served as a framework for the content analysis of the data collected.

The findings provide insights of how a teacher training programme can adapt teaching and learning to stay abreast with the technological advances of 4IR environments and how to innovate important discipline instructional strategies such as practical to remain viable in 4IR teaching and learning environments. Recommendations for research and teacher training practice are made.

Introduction

One of the things that have been brought about by the increasing pervasiveness of Fourth Industrial Revolution (4IR) and digital environments in HE is the need to design new courses and redesign existing courses in order for them to align with online instructional modes. Instructional design models are required to guide teachers and other instructional designers as they develop the courses. One of the widely used frameworks to guide instructional design is the ADDIE model (Durak & Ataizi 2016). The ADDIE model is constituted by the processes of analysis, design, development, implementation and evaluation (McGriff 2000). In this study, I used the ADDIE model as an instructional strategy to guide physical sciences' pre-service teachers as they learnt how to integrate computational thinking with the practical work instructional strategy. In the process, the pre-service teachers were exposed to the affordances of the ADDIE model in instructional design so that they may be able to use it to transition science practical work to online environments through computational thinking. It is hoped that the ADDIE model may become part of the pre-service teachers' pedagogical content knowledge that they will use as a tool to guide them if they have to transition other components of science teaching to online environments in their future classrooms.

One of the distinctive features of the 4IR environments is the increasing ubiquity of digital and computer technologies in everyday life. The pervasive advancements in digital and computer technologies have triggered changes in society and the labour market which include teacher education and schools bringing about increased complexity of the problems that people need to solve. The increasingly complex problems that people have to solve in the 4IR

environments require citizens to develop a special set of skills in order to adapt and function optimally. Wing (2006) identified computational thinking as one of the skills needed for solving problems in digital environments and therefore should be developed by all citizens in the 21st century. The fact that all citizens may need to develop computational thinking skills makes sense if we consider that Wing (2017) defined computational thinking as the thought processes involved in formulating problems and expressing the solutions in such a way that they can be effectively carried out by an information-processing tool such as a computer, machine or other digital gadgets.

Extending the capability of problem-solving from human minds to computers and digital tools through computational thinking is considered to be a remarkable intellectual revolution (Bundy 2007). Heintz and Mannila (2018) made an important observation that an increased exposure to the digital world raises the need to understand how that world works. Digital and computer technologies have infiltrated classrooms; however, it is alleged that teachers use them to support traditional teacher-centred classroom practices. Ndlovu and Meyer (2019) reported that in some South African schools, teachers struggle to use digital and computer technologies to enhance classroom practice. The teachers have been observed to use digital and computer technologies to perform mundane communication and administrative tasks at the expense of facilitating meaningful learning experiences for learners. In science teaching and learning in particular, Donnelly, O'Reilly and McGarr (2013) noticed that traditional classrooms can be enhanced through the use of digitally enabled simulations because they help learners to visualise abstract concepts.

There is an observed trend in which science and mathematics are increasingly becoming computational endeavours raising the need to develop the necessary sets of skills in learners (Weintrop et al. 2016). However, according to Israel et al. (2015) not all learners in the 21st century have the opportunities to develop computational thinking skills because some learners from low socio-economic backgrounds do not have access to digital technologies while some learners who may have access to the tools still lack the necessary computational competences. This has resulted in a digital divide that can be addressed systematically through education as some researchers such as Hu (2011) building on Wing (2006)'s idea that computational thinking is for all 21st-century citizens equate its importance to that of numeracy and literacy. Accordingly, there is a steady increase of literature that looks at the possibilities of preparing pre-service teachers in computational thinking skills for facilitation in their future classrooms. In one study by Vaca-Cárdenas et al. (2015), pre-service elementary teachers were taught computational thinking through coding with Scratch which is a simple programming language. The assumption was that the computational thinking skills developed by the pre-service teachers became part of their pedagogical content knowledge for digital classrooms.

In other studies, Yadav, Stephenson and Hong (2017), Mouza et al. (2017) and Yadav, Hong and Stephenson (2016) advocated for the redesigning of the methods courses to include computational thinking training as a way of ensuring the teaching of computational thinking in schools. This study adopted a similar approach by embedding computational thinking in the training of pre-service teachers for practical work facilitation in science classrooms. Practical work is an essential, distinguishing component of science (Millar 2009). Practical work is embodied in one of the three inherent goals of science teaching and learning of 'doing science' (Haslam & Hamilton 2010). The goal of 'doing science' is accompanied by the other two goals of 'learning science' and 'learning about science' and together broadly define what is taught and learnt in science classrooms.

Despite the importance of practical work in science teaching and learning, its implementation is characterised by several challenges that include lack of resources, insufficient training, time constraints and increased workloads, thereby negatively influencing how teachers design instruction and assessment activities (Yip & Cheung 2005). In this study, I explored the preparation of physical sciences' pre-service teachers for computational thinking integrated practical work instruction as a way of mitigating the science classroom implementation challenges. I used the ADDIE model as a method to guide the pre-service teachers as they engaged in the process of instructional design for integrating computational thinking and practical work instruction. The study has practice and theoretical implications as it describes an innovative way of training pre-service teachers to transform traditional practical work classrooms into virtual interactive environments and contributes insights on how to use computational thinking as problem-solving skill in physical sciences' classrooms.

Computational thinking

The 4IR has created a digital, complex and interconnected society that demands new kinds of skills that will enable citizens to function optimally by having the ability to solve problems in everyday life and workplaces. Wing (2017) identified computational thinking as an important skill that enables citizens to use digital tools, machines and computers together with the human mind to manage the complex 21st-century environment. Computational thinking enables people to engage in data practices, modelling and simulation practices, computational problem-solving practices and systems thinking practices (Weintrop et al. 2016) through the utilisation of digital and computer affordances. Accordingly, Wing (2017:8) asserted that 'Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer-human or machine-can effectively carry out'. Computational thinking itself is a set

of skills that include but not limited to (1) problem identification and decomposition, (2) algorithmic thinking, (3) abstraction, (4) data collection, (5) automation, (6) parallelisation, and (7) simulation (Yadav et al. 2017). This study is premised on the challenges experienced in science classrooms when implementing practical activity instruction, the increasing digital affordances in the 21st-century classrooms and how to empower the pre-service teachers through computational thinking skills.

Practical work in science

Practical work activities in science teaching and learning come in different forms and are diverse in nature (Millar 2009). Practical work provides authentic environments for abstract concepts, enables the facilitation of learner-centred teaching strategies, helps learners to develop science process skills, allows learners to behave like scientists and allows learners to experience the nature of science. As Chen and Eilks (2019) explained further, practical work is used by teachers to teach facts, concepts, relationships, theories or models that explain sub-microscopic scientific phenomena and laboratory techniques and is used to teach learners to identify objects. Therefore, practical work is significant in science education, and there are implications for science practical work practice in 4IR classroom environments. For this study, the emphasis is on how to prepare pre-service teachers to practice practical work strategies in 4IR classroom environments using computational thinking. Millar (2009) pointed out that the way a practical activity is designed and presented should align with the intended outcomes. Millar (2009) suggested a five-point checklist that can guide teachers when they are planning a practical work activity. The teachers should specify the following in the lesson plan for the practical work activity: (1) the question to be addressed, (2) the equipment to be used, (3) the procedure to be followed, (4) the methods of handling data collected, and (5) the interpretation of results. This five-point checklist for planning a practical work activity, the concept of computational thinking and the ADDIE model was used as a conceptual framework for the study.

The ADDIE model

In this study, the ADDIE model was used to guide the pre-service teachers as they engaged in instructional design and they learnt to facilitate science practical work in the context of 4IR. McGriff (2000) described the ADDIE model as an iterative process that consists of a series of steps, which are the analysis, design, development, implementation and evaluation. The evaluation step can be conducted formatively or for summative purposes. The study conducted by Budoya, Kissake and Mtebe (2019) demonstrated that the participants who participated in an instructional design activity

found the ADDIE model to be very useful as a guiding tool. The usefulness may result from the fact that the model provides structure around which the instructional designers can develop the learning materials (Hess & Greer 2016). The ADDIE model is considered to be the most popular instructional design model because the steps to be followed are well explained (Durak & Ataizi 2016). The study conducted by Ozdileka and Robeck (2009) seems to indicate that the analysis step can be complicated based on the finding that the instructional designers showed the highest level of concern when conducting analysis.

The concerns were based on the premise that there are several essential components that need to be analysed in order to initiate the instructional design process and not all of them may receive the required attention. When Durak and Ataizi (2016) were transitioning a face-to-face (F2F) undergraduate course to an online environment, they addressed a number of components in the analysis stage which included needs analysis, analysis of learners, content analysis, technical analysis and analysis of the online environment. This finding discussed above seems to suggest that the components that have to be considered in the analysis step should be comprehensive to allow for an effective instructional design process. The type of analysis conducted may also stem from the purpose of design or redesign of a course in the first place. The redesigning of courses may be prompted by the need to improve students' success (Shibley et al. 2011), the need to include learner-centred approaches that result in active learning (Hess & Greer 2016; Peterson 2003) and more recently the need to create learning environments that blend F2F and online instructions (Durak & Ataizi 2016; Hess & Greer 2016; Shibley et al. 2011). Hence, the instructional designers may only conduct a few types of analyses, and to illustrate the point, Shibley et al. (2011) conducted analyses to characterise the learners and to determine the learning objectives in order to initiate the instructional design process.

The design stage may also consist of a number of elements that have to be designed and depends on the context in which the instructional design is being conducted. In the study conducted by Durak and Ataizi (2016) to develop a F2F course of a programming language into an online course, the following components were designed: course objectives, course contents, course calendar, support services, communication methods, assessment and evaluation procedures, learning environments and the technological substructure. Consequently, the development stage is informed by the components designed in the previous step of the ADDIE model. In the study by Durak and Ataizi (2016), the development stage involved the preparation of the learning environment, the preparation of the course contents, dividing the course into modules and preparing the evaluation system which consisted of a set of learning assessments. The implementation stage entailed the application of the designed and prepared material, and in the case of Durak

and Ataizi (2016), the learning environment, which was LMS, was introduced, support was provided to the learning environment, communication was enriched and the course started.

The evaluation stage comprised the application of assessments that were made up of group work activities, homework and weekly opinions. The way the evaluation was conducted in the study by Durak and Ataizi (2016) supports the assertion made by Hess and Greer (2016) that the ADDIE model allows instructional designers to be more intentional when considering issues such as student engagement, learning and assessment. Despite the perceived usefulness of the ADDIE model in guiding instructional design as described above, William van Rooij (2010) opined that the model may not be sufficient in itself to guarantee the best results. William van Rooij (2010) suggested that the ADDIE model needs to be complemented by other frameworks or concepts such as project management in order to ensure sustainability of the instructional design process by being able to control other contextual factors that may influence the process. These contextual factors may include how the instructional design process is funded and whether there are sufficiently equipped instructional designers for the course. There are other instructional design models in literature, and Bajracharya (2020) gave the Kemp and ASSURE (analyse students, state standards and objectives, select strategies, utilise strategies, require student participation and evaluate and revise) as additional examples. However, Göksu et al. (2017) posited that most instructional design models are built upon the ADDIE model, and that is why, it was selected to be used in this study.

Methods and study context

In this interpretive, single, explorative and longitudinal case study which spanned over 2 years, data were collected by means of reflections from 25 physical sciences' pre-service teachers from when they were in their third year to when they were in their fourth year of the BEd degree studies. As part of the physical sciences' methods course, the pre-service teachers were prepared to facilitate practical work activities for learners through lectures, simulated teaching, micro-teaching and teaching practice. Over the period of two (2) years in which the participating pre-service teachers were in the third and fourth year, respectively, they engaged in teaching practice for a total period of six (6) months. Thirteen of the pre-service teachers conducted their teaching practice in the rural parts of Free State province, while 12 of the pre-service teachers were placed in rural parts of KwaZulu-Natal for their teaching practice. This pre-service teachers' background is important to consider because the experiences they had in largely rural and under-resourced schools influenced the decisions they made as they engaged in the instructional design process. The possible influence of the under-resourced rural classroom

experiences on the pre-service teachers may also have bearing on the findings of this case study.

Data for this study were collected when the participating pre-service teachers collaborated through group work in using the ADDIE model to conduct instructional design on facilitating practical work through computational thinking. The pre-service teachers worked in groups of five members, and therefore, there were five groups in total. Using the three-month long third-year practicum experiences, the groups of pre-service teachers guided by the ADDIE conducted a needs analysis and the design stages by reflecting on the opportunities and challenges they experienced and observed when facilitating practical work for learners in the physical science classrooms. The identified needs (challenges) and the designs to address the challenges (opportunities) that they reflected on were submitted to the researcher. In the fourth year, after receiving training on computational thinking as part of the fourth year methods course in the first semester and attending a 3-month teaching practice, the five groups of pre-service teachers received further prompts to rework the needs analysis and design of solutions in order to effectively facilitate practical work through computational thinking in the physical sciences' classrooms. The training on computational thinking consisted of two 2-h-long lectures, one 3-h-long practical work activity and suggested literature readings on computational thinking. The reworked needs analysis and the design reflections were submitted to the researcher in August 2019. In the development stage, the pre-service teachers prepared a 1-h-long practical work activity at the end of August 2019 according to the design checklist suggested by Millar (2009:10) on:

- the question to be addressed
- the equipment to be used
- the procedure to be followed
- the methods of handling data collected and
- the interpretation of results.

The groups of pre-service teachers proceeded to gather the materials required for them to be able to facilitate the practical work as a way of fulfilling the development stage. For implementation, one member from each group was selected to teach the lesson to the rest of the pre-service teachers (simulated teaching). After the lessons were taught, the groups sat separately to reflect on what worked and what did not on the instructional design they conducted to facilitate practical work through computational thinking as the last part (evaluation) of the ADDIE process. The pre-service teachers submitted a write-up of how they conducted the instructional design process to the researcher. A particular instruction was given in order for the groups to clearly show what they did in the different stages of the ADDIE model.

Data analysis

Content analysis guided by the ADDIE model, computational thinking and Millar (2009) checklist for designing practical work activities was used to make sense of the data collected. The process entailed reading the submitted materials and coding them accordingly under analysis, design, development, implementation and evaluation. Therefore, for each stage of the ADDIE model that the pre-service conducted, the contents were analysed for practical work facilitation and use of computational thinking. Table 8.1 shows an extract from the reflections and instructional design codebook to help understand how the data collected were processed.

Ethical considerations

This chapter was produced from a research project ethically cleared by the University of the Free State Ethics Committee under the Reference number: UFS-HSD2019/0217/3007. Accordingly, the permission to conduct research was granted by the University Gatekeepers. The participants signed consent letters and their identities will remain anonymous.

TABLE 8.1: Excerpt from the reflections of instructional design codebook.

Code	Description of code	Example data excerpt	Category
Analysis	• Needs analysis for effective implementation of practical work • Classroom challenges related to practical work implementation	Not all practical work activities are implemented	Needs analysis for facilitating practical work in physical sciences' classrooms
Design	• Computational thinking strategies to be used • Instructional strategies to be used for practical work implementation	Use of an online lab that can be accessed by anyone with a computer, tablet, smartphone, etc.	Designs for facilitating practical work in physical sciences' classrooms
Development	• The purpose and content of practical work • The equipment to be used • The procedure to be followed • The methods of handling data collected • The interpretation of results	Download the apps and videos of the same practical on YouTube	Development of the practical work through computational thinking
Implementation	• Integrating computational thinking and practical work • Use of virtual environments to facilitate	Group A used the EveryCircuit virtual laboratory to facilitate the verification of the Ohm's Law by investigating the relationship between current and resistance	Implementation of the practical work through computational thinking
Evaluation	• Reflections on the process of instructional design	-	Evaluation of the instructional design process

Findings of the study

In the discussions that follow, the five groups are referred to as Groups A to E. The findings of the study are organised according to the data collected as the five groups of the pre-service teachers engaged in the different stages of the ADDIE model grouped under three themes as follows: (1) needs analysis and designs for facilitating practical work in physical sciences' classrooms, (2) development and implementation of the practical work through computational thinking, and (3) evaluation of the instructional design process.

Needs analysis and designs for facilitating practical work in physical sciences' classrooms

Analysis in the third year

In this stage, the groups conducted the needs analysis of facilitating practical work for learners in secondary school classrooms. In order to do so, the five groups reflected on the opportunities and challenges for classroom practical work practice. These challenges and opportunities are presented first as the pre-service teachers viewed them in the third year, and second, as they viewed them in the fourth year after they completed a course in computational thinking. In the third year, the pre-service teachers identified some challenges that they considered to stand in the way of effective practical work classroom practice. The most common challenge identified by the groups was the lack of equipment and materials to support practical work activities and the lack of resources led to other teaching and learning challenges. It is very difficult for schools from low socio-economic backgrounds to secure proper science materials and equipment because as Reid and Shah (2007) put it, science laboratories are very expensive and difficult to maintain. Group B reflected on some schools located in rural areas saying:

> 'Some learners in rural areas are only taught theory and calculations, and a few times teachers conduct practical demonstrations. The learners are not familiar with practical work materials and equipment in science laboratory settings'. (Participants, Group B, date unspecified)

The lack of materials resulted in limiting the learners' exposure to hands-on activities and development of practical work skills such as the handling and manipulation of equipment and materials. Group A showed how the limited resources affected the teaching and learning of practical work, resulting in overcrowding and reduced teacher commitment to the practical work instructional strategy. The group reflected as follows:

> 'Not all practical work activities are implemented. Some are left out because of the lack of motivation on the teacher's part and the materials were not available; those

> that were available were outdated. The classes had large groups of learners, and the materials were limited. The teacher had to divide the class into groups of 10'. (Participants, Group A, date unspecified)

The excerpt above shows that some of the available materials were not useful because they were outdated and they were not replaced. Learners did not benefit much from the materials, and they had to crowd over the few that were in good condition. Considering that practical work is crucial for 'doing science' (Haslam & Hamilton 2010) and other important outcomes (Chen & Eilks 2019) in science education, the failure to implement the instructional strategy compromises learning experiences. Group D reiterated that the materials found in the schools were very old, and the schools seemed to have trouble in replacing these materials. The group reflected as follows:

> 'The materials that were used were very old as the school does not purchase any new materials for the physics laboratory, some of the materials like magnets had already lost their magnetism as they are not well kept and are not disposed properly. Teacher's demonstration of practical work was a widely used teaching strategy and learners observed quietly whilst taking notes. The teacher explained every step as he was conducting the experiment, for learners to follow and ask questions where they do not understand'. (Participants, Group D, date unspecified)

Some of the teacher-centred instructional strategies seemed to be caused by the lack of materials. However, Group C highlighted a case where the use of teacher-centred practical work facilitation occurred in instances where materials were available for learners to use. The resulting challenge was that the teachers' methods of teaching did not allow learners to explore or actively construct meaning from the practical work activities. The group reflected as follows:

> 'The main teaching method that was used was the direct teaching style. Teachers planned the task and led the class through a task step by step. He/she gives instructions on what to do, where to do it, how to do it and when to do it. The teacher would read out the first instruction for her learners and wait for them do it before moving to the next, at the same she was busy checking whether learners are doing what she was reading for them. In this way she was in charge of everything, her learners were only following her instructions not getting a chance to do the practical on their own so they can do mistakes and learn from them'. (Participants, Group C, date unspecified)

The main challenges that impeded the effective practical work classroom practice gleaned from the pre-service teachers' reflections stemmed from lack of sufficient resources and equipment because of overcrowding, failure to replace expired materials and damaged equipment and schools that could not afford to buy resources. The other challenge was that teachers tended to use teacher-centred instructional strategies to teach practical work. Despite the challenges, the pre-service teachers suggested some solutions to the identified that they considered as opportunities that enabled the implementation of practical work activities in the physical

sciences' classrooms. Group E suggested how the shortage of materials was mitigated by substituting the prescribed materials with locally available ones and borrowing from neighbouring schools. The group reflected as follows:

> 'There was a shortage of materials to conduct proper experiments at the school and most experiments were not successful. For some experiments, learners were asked to bring to class materials that they could find at home while some equipment and materials were borrowed from neighbouring schools. The equipment was returned after use.' (Participants, Group E, date unspecified)

Similarly, Group B thought that they could ask for help from schools that could afford to share their resources either through loaning materials and equipment out or have learners from other schools come and conduct practical work activities in their laboratories. The group reflected as follows:

> 'I would negotiate with the school that is located few kilometres away from my school, but having all equipment or materials, to accommodate my learners by borrowing their materials for temporary usage and we will bring them back after demonstration. I would negotiate with school's leadership to allow learners to attend practical demonstrations activities at the nearest school that has all the equipment and knowledgeable teachers who can thoroughly do the practical work.' (Participants, Group B, date unspecified)

Design in the third year

Group C which had indicated that teachers used teacher-centred instructional strategies when facilitating practical work for learners and Group E who observed that sometimes teachers used household materials when they did not have the prescribed materials, both suggested the use of educational technologies such as videos, computers, pictures and interactive white boards. Group C reflected as follows:

> 'Since there were no enough materials to do all the experiments based on the topic we could download the videos of the same practical on YouTube and bring a computer in the classroom so that the learners can watch the practical.' (Participants, Group C, date unspecified)

Similarly, Group E also suggested using a combination of educational technologies with locally available materials to ensure that learners are engaged in practical work activities in authentic environments. The group reflected and gave an example as follows:

> 'Bringing concepts that seem abstract to learners to life by using visuals and concrete learning experiences improves understanding and application of what they learn in class in everyday life. Example – using the whiteboard to display photos, a balloon and a ruler on the practical demonstration of forces of attraction and repulsion.' (Participants, Group E, date unspecified)

While the idea of replacing some prescribed materials that were not available with household and other locally available materials, and the use of educational

technologies were very practical and useful, the notion of borrowing materials from neighbouring schools might not have been a sustainable solution to address the challenges. Yip and Cheung (2005) indicated that among the things that concern teachers in terms of practical work implementation is lack of the necessary resources. Akuma and Callaghan (2019) emphasised the notion that a considerable number of schools in South Africa lack resources for practical work.

Analysis and design in the fourth year

However, in the fourth year after receiving training on computational thinking by attending two lectures and a practical work activity, reading three articles on computational thinking and completing another three months of teaching practice, the groups reworked and refined the needs analyses and the design of solutions to the challenges experienced in physical sciences' classrooms when facilitating practical work for learners. The designs described were influenced by how the pre-service teachers could use computational thinking as a problem-solving tool to address the challenges experienced when facilitating practical work because of the training they had received in the methods course. Through computational thinking, people engage in thought processes to formulate problems and their solutions (Wing 2017).

Group E reflected on the potential of using online resources such as virtual labs applications that can be accessed through smart phones, computers, tablets and other gadgets in supporting the implementation of practical work in science classrooms. The group reflected as follows:

> 'Online laboratories allow learners to have virtual experiences of practical work activities. The learners would need to download an application that contains the desired experiments on electronic gadgets such as the computer, tablets and smart phones. For some applications the learners may need to register and create usernames. In performing the experiments, the applications allow learners to manipulate variables, select materials and they can record what they observe.' (Participants, Group E, date unspecified)

The group seemed to begin to appreciate the advantages of embracing some of the educational technologies that might be accessible through the gadgets that learners may already be possessing. Donnelly et al. (2013) asserted that the use of simulations and other educational technologies improves learning in science classrooms. Similarly, Group D made a connection between the needs of physical sciences' practical work implementation and a design of a possible solution as follows:

> 'Some practical work activities such as experiments require learners to conduct several trial runs and measurements in order to get accurate results. This process is hampered by lack of resources and time in most schools. Due to lack of materials students cannot perform experiments accurately hence they require extra aid.

> These challenges can be resolved using computational thinking skills by means of simulations.' (Participants, Group D, date unspecified)

In showing some of the challenges that can be resolved by the use of computational thinking skills in virtual laboratories, Group B enumerated the following:

> 'In chemistry, laboratory clothes [*personal protective equipment*] are costly for learners. Some of chemicals are contaminated and cannot give the desired results. There must be lab assistants to monitor learners during the experiment, because learners tend to lose focus if the educator is away from them. As a result, it could lead to learners to play with chemicals. Learners fail to obey the rules of laboratory they tend not to take them serious.' (Participants, Group B, date unspecified)

The same group went on to list some of the challenges that they thought affected practical work in physics. They reflected further as follows:

> 'In physics the shortage of toys more especially trolleys to explain better the concept of momentum (elastic and in elastic collision) and the shortage of electrical materials such as voltmeter, ammeter and etc. hinders learners from learning.' (Participants, Group B, date unspecified)

Group C added the limited preparation time for teachers and constrained school budgets as some of the challenges by saying:

> 'Teachers spend a lot of time preparing materials in science laboratories. The equipment and materials are very expensive for most schools. Some of them are not conducted because the materials and equipment are not enough to mount specific apparatus for example the heating and cooling curve experiment apparatus.' (Participants, Group C, date unspecified)

Yip and Cheung (2005) mentioned how teachers have limited available planning time for practical work instruction and assessment because of intensified workloads. Group A seemed to sum up the pre-service teachers' design of how to effectively implement practical work in the physical sciences' classrooms possibly influenced by the literature they read and based on the needs identified as follows:

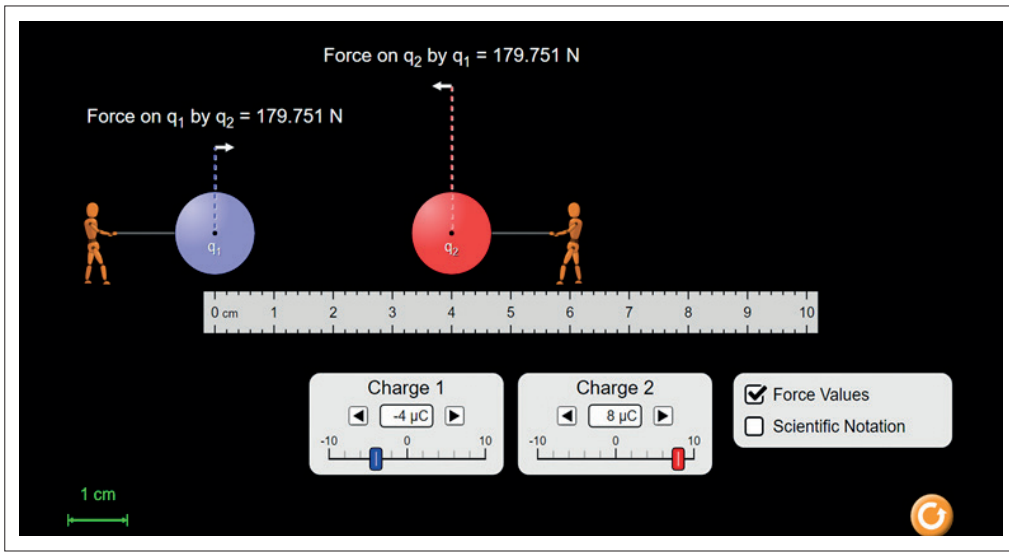
> 'Computational thinking is the application of computer science and software to solve scientific problems. It can be used in physical sciences to integrate education and technology. It creates a fun learning environment to stimulate learner concentration. It reduces workload on both the learners and teachers. It's a useful tool for learners with low cognitive skills, and stimulates critical thinking.' (Participants, Group A, date unspecified)

Simulations are considered to improve the learners' conceptual understanding, reduce time demands, improve predictions of the results of experiments and impact positively on the learners' attitudes and perceptions of learning in science classrooms (Donnelly et al. 2013). In the following section, the development and implementation stages of the ADDIE process are presented by describing the lesson plans of the practical work activities that employed computational thinking.

Development and implementation of the practical work through computational thinking

In order for the pre-service teachers to implement the practical work activities, they selected virtual laboratories that enabled them to use four computational thinking skills which were problem decomposition, making use of algorithms, pattern recognition and pattern generalisation and abstraction. Group A used the EveryCircuit virtual laboratory to facilitate the verification of the Ohm's Law by investigating the relationship between current and resistance. Group B facilitated the verification of the Boyle's Law using the PlaxiLabs virtual laboratory, while Group C used the CK-12 virtual laboratory to determine the heating and the cooling curves of water. Group D facilitated a practical work to determine the relationship between force and velocity, and Group E facilitated a practical work activity to determine the force exerted by charge 1 (q_1) on charge 2 (q_2) and vice-versa as the distance between the two charges is varied. Both Group D and Group E used the Physics Education Technology (PhET) virtual laboratories. For example, the virtual laboratory used by Group E looked like Figure 8.1, and with the click of the mouse, the learners would be able to manipulate the variables.

Problem decomposition was evident when investigative questions and hypotheses were formulated for the practical work activities. Algorithms were used in the form of the steps followed when manipulating the variables in order to collect data. The analyses of the data collected enabled pattern



Source: University of Colorado (n.d.).
PhET, Physics Education Technology.

FIGURE 8.1: PhET virtual laboratory on Coulombs Law of electrostatics.

recognition defined by the relationships such as the Boyle's Law, the Ohm's Law and the relationship between force and velocity. Chen and Eilks (2019) pointed out that identifying relationships is one of the intended learning outcomes for conducting practical work in science classrooms. Groups C and E used the practical work activities to teach concepts. Ultimately, pattern generalisations and abstractions from the analysed data are made as investigative questions are addressed and hypotheses are confirmed or rejected. The computational thinking skills were also embodied in the checklist to be used by teachers proposed by Millar (2009) when facilitating practical work that is identifying the question to be addressed (problem decomposition); the equipment to be used (virtual laboratory); the procedure to be followed (algorithms); the methods of handling data collected (pattern recognition/ analysis) and the interpretation of the results (pattern generalisation and abstraction).

Evaluation of the instructional design process

The pre-service teachers evaluated the instructional design process for integrating practical work with computational thinking that they had gone through by way of reflections. It seemed as if they had developed positive perceptions on the integration of computational thinking with practical work. They were able to see how the use of computational thinking and virtual laboratories helped them to solve some of the challenges they had experienced in the science classrooms. However, the limitation is that they did not implement the instructions that they had designed in real classrooms because these were tried in simulated conditions. Wei, Chen and Chen (2019) confirmed that pre-service teacher learning experiences, reflections, literature readings and searching online sources are some of the ways through which teachers learn to facilitate practical work in science classrooms. Group B acknowledged that by integrating computational thinking with practical work, learners developed computational and problem-solving skills in physical sciences. Wing (2017) identified computational thinking as a problem-solving tool through the use computers, machines and similar gadgets. The group reflected as follows:

> 'Learners develop computational skills by solving scientific problems and think logically. Learners are able to explore real-life situations using computers. They are able to use metres connected to computers to record accurate results. They are able to interpret results and make constructive conclusions.' (Participants, Group B, date unspecified)

Group C reiterated that learners may develop important skills such as science process skills and added that active learning is possible because some of the applications are interactive. The group reflected as follows:

> 'With the aid of this app (CK-12) learners' computational thinking is well enhanced and their process skills are well developed. This is because the app is designed in such a way that learners have a platform where they can ask questions and

> request for further instructions, and any clarifications. It allows teachers to provide immediate feedback of the experiment, comments regarding the experiments.' (Participants, Group C, date unspecified)

The interactive nature of the virtual laboratories and the benefits that come with it may be one of the reasons why science is increasingly becoming a computational endeavour as suggested by Weintrop et al. (2016). Through the experience of designing computational thinking integrated practical work instruction, the pre-service teachers seemed to gain ways of converting traditional classrooms into digital environments. Group E reflected as follows:

> 'What we learnt and we think we will use in our future physical sciences classrooms, is to use as many applications/software we can access to teach our learners. We are saying this based on our project/research we've seen how effective computational thinking is, in both teaching and learning.' (Participants, Group E, date unspecified)

From what the pre-service teachers in Group D say in their reflections below, it seemed as if they believed that the learners would not have trouble working in the virtual laboratories, which is one indication of the pervasiveness of the 4IR tools. In fact, Bundy (2007) thought that computational thinking is a skill that is prevalent in learners of school-going age. The group reflected as follows:

> 'It is much easier to explain the lesson when using computational thinking as compared to the traditionally method. Computational thinking allows learners to be themselves [or] it builds confidence of learners. Learners of this time are so familiar with technology and they use it every time. So if you use computational thinking in your classroom, it will be much easier to teach effectively and learners will also learn effectively because your lessons will not bore them.' (Participants, Group D, date unspecified)

Weintrop et al. (2016) pointed out that a thoughtful and well-planned use of computational thinking tools is beneficial to the learning of science. The use of the ADDIE model by the pre-service teachers as they engaged in the instructional design shows how the model can be used to ensure effective teaching and learning by addressing needs in learning and learning environments (Durak & Ataizi 2016; Hess & Greer 2016; Peterson 2003; Shibley et al. 2011). The learning needs and learning environments include the transition of science education including practical work from physical to online environments. The study has value in that it serves as an example of how teachers and pre-service teachers alike may incorporate online and virtual learning environments in the traditional F2F classrooms. The findings of the study also raise practical implication for teacher preparation in that programmes need to be intentional in preparing pre-service science teachers to be functional in both physical and online classrooms.

Conclusion

The study set out to explore the preparation of physical sciences' pre-service teachers in computational thinking integrated practical work and how it

influenced their instructional design of practical work activities as guided by the ADDIE model. The training in computational thinking improved the pre-service teachers' abilities to identify problems and formulate solutions while preparing them for the increasingly pervasive digital and computer technologies in the classrooms. Digital- and computer-based computational thinking is one of the skills required by 21st-century citizens including pre-service science teachers, in order to be functional in the 4IR everyday life and work environments. The pre-service teachers were able to conduct the needs analysis and design that led to the use of online tools in the facilitation of practical work. As there is an increased pervasiveness of digital technologies in both HE and schooling sectors, most of the learning programmes need to be redesigned for online instruction compatibility. It is, therefore, prudent to prepare pre-service teachers to be able to engage in instructional design for online science teaching including practical work facilitation. The findings indicate how the training in computational thinking enhanced the pre-service teachers' instructional designs in mitigating the challenges that hinder the effective implementation of practical work in science classrooms. The use of the ADDIE model by the pre-service teachers helped them to systematically gather data that they used to engage in reflection which was an important learning tool for them. The study is limited because the implementation of the instructional designs was conducted in simulated conditions, and for this reason, further studies need to be conducted in which the pre-service teachers can implement computational thinking integrated practical work in real classrooms.

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Chapter 9

Transforming the school curriculum and pedagogy through integrating social media technology in the context of the 4IR

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Abstract

In recent years, the influence of the social media technology has attracted considerable attention in organisations including academia with many contemplating its adoption as part of the digital transformation efforts ideal for the Fourth Industrial Revolution (4IR). This chapter explores the merits of integrating the social media technology in the HE curriculum despite the technological dilemma of some academics who continue to grapple with the use of social media, particularly those educated during the type-writer era. Some academics still wonder what WhatsApp, Twitter, Facebook, Instagram,

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LinkedIn or YouTube are, and it is the objective of this chapter not only to establish the receptive levels of classroom practitioners in embracing social media into their curricular and pedagogical activities but also to assess their perceptions towards its integration in the 4IR era curriculum. Adopting a pragmatic paradigm and utilising an exploratory sequential mixed methods design as the strategy of inquiry, the data to embellish the discussion in the chapter were generated through structured and unstructured questionnaires. A total sample size of 100 systematically and purposefully sampled members of the South African School Management Teams (SMTs) took part in the study. The data analysis followed both descriptive and thematic approaches culminating in such key findings that while quite a good number of the young classroom practitioners have embraced the advent of the 4IR and the use of social media technology in their professional life, there remains some resistance to the new technology from the old guard. The conclusion drawn was that because many classroom practitioners in South Africa are now seized with the intriguing challenge of embracing the 4IR initiatives, integrating social media technology into their school curriculum and pedagogical practices ought to be the norm. Among the recommendations made was that South African HEIs need to impress upon all levels of academia to consider adopting the social media technology as part and parcel of their curricula and pedagogy, particularly in the 4IR.

Introduction

The social media technology has attracted considerable attention in academia, and many are considering adopting it in their day-to-day operations (Mutekwe 2015). Proponents of curriculum leadership advocate adopting the benefits offered by the social media technology to pedagogy (Kumar 2018). For them, the social media technology can successfully transform the pedagogical landscape of educational institutions, and it is in this light that the objectives of this empirical research are as follows: to establish the benefits drawn from integrating the social media technology into curriculum leadership and pedagogy in educational institutions; to determine the social media technological platforms' learners are experienced in; to examine the uses of the social media technology in enhancing improved learners or students' performances and to identify who the curriculum leaders are and what aspects of curricular leadership they have to deal with via the social media. The main thesis of the discussion herein is that social media has now become so ingrained in today's society that learners or students can hardly operate without constant reference to social media technological platforms such as Instagram, Facebook, WhatsApp and Twitter, among other sites (Kumar 2018). Dubrovsky (2011) notes, however, that there is a misconception that needs to be deconstructed, and this concerns the need for classroom practitioners to be flexible or amenable to change their perceptions of traditional teaching

and learning or pedagogical approaches so that they remain relevant to the needs and trends of today's learners (digital natives).

It is in this light that they need to seriously consider the merits of integrating the social media technology into classroom practice largely because when carefully adopted, social media technology is an interestingly useful tool rather than a distraction (Dubrovsky 2011). Seen in this light, this chapter discussion is informed by the following research questions: what social media technological platforms are ideal in transforming the school curriculum and pedagogy? How best can the social media technology be adopted in the 4IR to enhance improved student learning? How can curriculum leaders as pedagogists transform the school curriculum and pedagogical practices in the 4IR? Who are the curriculum leaders and what aspects of curriculum and pedagogical practices do they need to transform in the 4IR? And what are the curriculum leadership transformations necessary for the 4IR? Be that as it may, educational institutions thus ought to draw on the benefits the social media technology offers as part of the pedagogical tools if they are to continue to harness its potential in the digital transformation in the face of the 4IR (Devitt 2010; Ryan 2014). The research is significant in that its findings are expected to go a long way in raising practical, theoretical and policy consciousness on the usefulness of the social media in educational institutions. Further to this, it is also expected to conscientise classroom practitioners on the pedagogical importance of WhatsApp, Twitter, Instagram, Facebook and LinkedIn as forms of social media. Theoretically, the study is envisaged to contribute important insights to the existing body of literature on social media technology in education and society (Prensky 2010). Furthermore, the findings are expected to influence policy through sensitising policy-makers on the need to cater for digital natives in their future policy enactments (Greenhow 2011).

Literature review

The literature review for this study is grounded in the Vygotskian socio-cultural perspective, which Mutekwe et al. (2013) asserted regards knowledge as a social construct, a product of human social interaction. Advocates of this theoretical framework (e.g. De Valenzuela 2010; Kozulin 2002; Vygotsky 1987; Wretch 2004) agreed that tool-mediated learning provides effective scaffolding of learning by transforming the learners' lower mental functions to higher mental ones, especially if the mediation effort is provided within the learners' zones of proximal development (ZPD). The concept of ZPD as used by Vygotsky (1987) describes the range or difference between what learners can do on their own and what they are able to do following the assistance of adults or more capable peer collaborators. In the context of this study, the 4IR requires social media technological platforms such as Facebook, Twitter,

Instagram, LinkedIn and Skype, which are construed as important technological learning tools that institutions of learning in general and educators in particular need not overlook in their professional life, especially in view of the fact that as part and parcel of the this 4IR, this technology has invaded the global villages (Casey & Evans 2011). The notion of scaffolding implicit in this theoretical framework (socio-cultural perspective) to teaching and learning describes learning as pre-supposing mastery of prior knowledge (lower mental functions) as a condition necessary for the development of new forms of knowledge (higher mental functions). Modern day constructivist learning environments in educational institutions require that learners integrate or adopt the social media technology given its popularity with current learners, which Prensky (2010) regards as digital natives.

Kumar (2018) and Kaplan and Heinlein (2013) viewed the concept social media as describing a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0 to allow the creation and exchange of user-generated content. Deploying such technology in pedagogy has enormous merits, which include ensuring that lessons, announcements, lecture notes and feedback on assignments are easily and readily availed to the students (Mutekwe et al. 2013). As noted by Prensky (2010), the social media technological platform has introduced substantial and pervasive changes to communication in organisations, and communities and students in academia need to tape into this innovation. According to socio-cultural educational technologists (e.g. Amory 2010; Nielsen 2012), there are many potential benefits general classroom practitioners and curriculum leaders derive from social media usage in their classrooms because modern day Internet users and scholars continue to spend more time with social media sites than any other type of sites, and therefore, educators need to exploit this practice. For Tang and Whinston (2012), the information emanating from the USA Internet usage shows that the total time spent on social media by scholars in the USA across PC and mobile devices increased by 37% to 121 billion minutes in July 2012 compared to 88 billion minutes in July 2011. To content contributors, the benefits of participating in social media have gone beyond simply social sharing to building reputation and bringing in career opportunities, community development and monetary income (Greenhow & Robelia 2009). Viewed from this perspective, educators in academia should draw on the existing student interest in social media or Internet use to advance their intended learning outcomes (Friedman & Friedman 2013). The relationship between social media and social networking is that while the former offers platforms for human interaction in virtual communities, in the 4IR the latter provides for the scaffolding upon which successful interaction and community-building efforts are created (Maloma 2020).

The 4IR is thus basically a concept coined in 2016 by Klaus Schwab, Founder and Executive Chairman of the World Economic Forum (Lavopa &

Delera 2021). As an epoch, it is characterised by the convergence and complementarity of emerging technology domains, including nanotechnology, biotechnology, new materials and advanced digital production (ADP) technologies. The latter includes 3D printing, human-machine interfaces and AI, and is already transforming the global industrial, educational and social landscape (Schwab 2016). Incorporating ADP technologies into industrial production processes has given rise to the concept of Industry 4.0, also known as the Smart Factory – one that learns as it works, continuously adapting and optimising its own processes accordingly (Lavopa & Delera 2021). A further and brief description of the 4IR by Maloma (2020:16) also shows that it is characterised by a fusion of technologies that blurs the lines between and among the physical, digital and biological spheres, which are collectively described as the cyber–physical systems. This implies that it is marked by the emerging technological breakthroughs in several fields including robotics, AI, nanotechnology, quantum computing, biotechnology, the IoT, the Industrial Internet of Things, decentralised consensus, fifth-generation wireless technologies (5G), additive manufacturing and fully autonomous vehicles (Maloma 2020). Basically, the aforementioned means that the 4IR is an era characterised by the current and developing environment in which disruptive technologies and trends such as the IoT, robotics, VR and AI are changing the way people live and work (Ndung'u & Signe 2020). It is thus typified by a fusion of the digital, biological and physical worlds, as well as the growing utilisation of new technologies such as AI, cloud computing, robotics, 3D printing, the IoT and the use of advanced wireless technologies, among others (Kaplan & Heinlein 2013; Ndung'u & Signe 2020).

In the context of teaching and learning (pedagogy) and by deploying the Vygotskian socio-cultural perspective, the aforesaid implies that the elements of the 4IR help to scaffold learning as parts of the material and psychological tools (Vygotsky 1987). If used in the students' zones of potential development, the IoT will, for example, convert the students' skills from lower to higher mental or psychological functions. Essentially this implies that the 4IR enables the complete communication of all relevant student information at every stage in the production chain, with their educators creating separate production sectors for each process and informing how they relate to each other and further by bringing together learning processes such as socio-cultural mediation, communication and collaboration in their respective communities of practices. In this manner, effective pedagogical effectiveness is realised within a given community of practice (Lave & Wenger 1998; Nieuwenhuis 2016). This is unlike the education, curriculum and pedagogy typical of the First, Second and Third Industrial Revolutions, whose assumptions Maloma (2020:15) summarises by saying the First Industrial Revolution (1IR) lasted from about 1765–1830 and was mainly confined to Britain and was characterised by breakthrough technologies in education and technology

that included mechanisation, water and steam power. In Maloma's views, the curriculum and pedagogy of the Second Industrial Revolution (2IR) were characterised by breakthrough technologies that included mass production and assembly lines and lasted from about 1870–early-20th century and took place in Britain, continental Europe, North America and Japan (Ndung'u & Signe 2020). As for the 3IR, the curriculum and pedagogy were characterised by breakthrough technologies that basically included computers and automation. Essentially, the aforementioned implies that these industrial revolutions were the characteristic of epochs in which electronics and information technology were used to automate production, and this occurred since the middle of the last century from about the year 1969 and brought about electronics, telecommunications and of course computers, which subsequently ushered in the 4IR happening to this day (Ndung'u & Signel 2020).

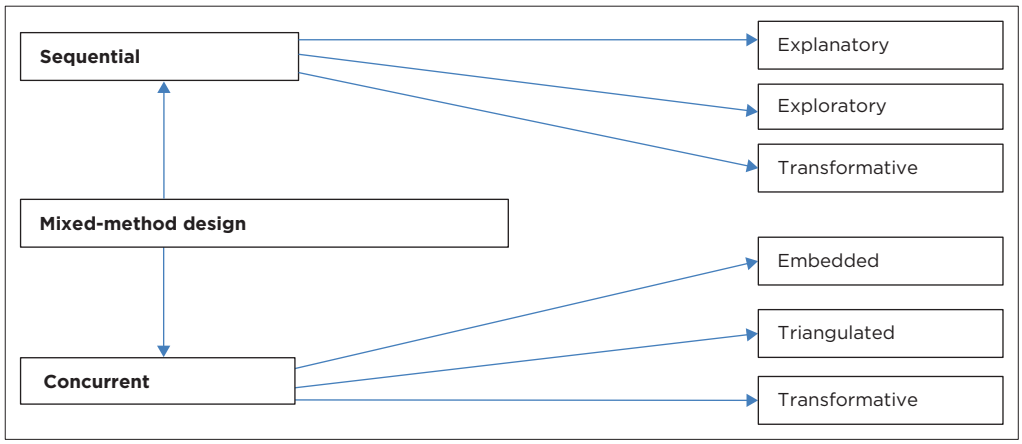
Drawing from the views of educational technology researchers, it is important to note that in order to effectively motivate today's students, which the likes of Prensky (2010) and Verran (2008) refer to as the digital natives (children born in the period between 1980 and 2006) whose everyday life experiences are characterised by Internet connectivity, it is important that educators incorporate social media in their pedagogy. Further justifying this view, which is presumably also true of the South African context as well despite the constraints student teachers and their learners encounter, Rosen and Nelson (2008) argued that such learners prefer to receive information quickly from multiple media sources because they are so obsessed with technology that they can hardly carry out any scientific operation without reference to electronic gadgets such as calculators. The above views also give rise to the need for making a distinction among the digital natives, digital immigrants and the digitally challenged on the grounds that digital immigrants unlike digital natives are people born between 1695–1980, who can use technology but with great effort (Verran 2008). Also known as Generation X and often contrasted from Generation Y, who are the children born in the age of technology (Prensky 2010), the latter is a generation of traditionalists born between 1925–1945 and who barely know how to use a bread toaster, PC or iPhone are regarded as the digitally challenged (Prensky 2010). It is in view of the digital natives' quest for educational skills such as parallel processing and multitasking, processing sounds and picture, video before texts, random access to hyperlinked multimedia information, preference for simultaneous social interaction or networking, learning just-in-time, instant gratification and immediate rewards and using instantly useful or relevant content that adopting social media technology in the classroom would certainly be exciting and fun, particularly for the digital natives and even for some digital immigrants (Baird & Fisher 2006; Vigdor & Ladd 2010).

For Selwyn (2012), it is undeniably true that the school curricular leaders have key roles to play in the overall institutional culture and direction of the institution. Further to this, Marzano, Walters and McNulty (2015), in a study of principals as curriculum leaders reported a strong correlation between the impact of school leadership, pedagogy and student achievement. As curriculum leaders, school principals are always key in ensuring that the school tone is always of a high quality, and to ensure this, they need the full cooperation and support of the entire teaching staff (Marzano et al. 2015). Audi (2009) maintained that it is common that the transfer (devolution) of curriculum leadership within the secondary school departments is a strategic decision that aligns with the vision of the whole school to be inclusive of the strengths of the staff and possibly students. As such, Hallinger (2018) contends that despite the use of the social media technology having become so fashionable that except in very remote rural areas, virtually no one student goes to school without a mobile gadget to extend learning beyond the classroom setting. In the South African context, this view, although true to some extent, does affect school learning, and for many classroom practitioners, even those using flipped classrooms, belonging to a *Facebook* group, is as important as having a YouTube video as part of blended learning (Kukulska-Hulme & Viberg 2017). Prensky (2010) further noted that through the use of online content management systems, students can be offered opportunities for access to a variety of learning resources. Further to this, because many of them have the *Facebook* app on their phones, it means they can have constant access to course information without having to log into a completely different system (Boyd &Ellison 2008).

Methodology

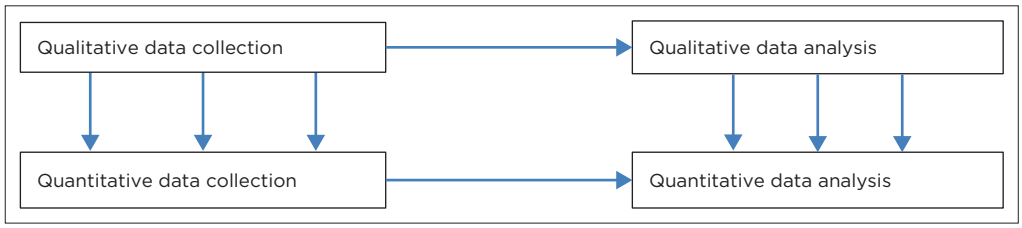
The paradigm within which this study is situated was pragmatism, and the design followed was exploratory sequential mixed methods. Noting that the mixed methods' research designs can be either sequential or concurrent, this study chose to follow the former. This implies that in the data collection and analysis processes, the qualitative research approach preceded the quantitative one. A brief overview of the mixed methods' research designs is illustrated in Figure 9.1.

The choice of the design was motivated by the researcher's interest in generating data that not only have an objective ontology but also have multiple subjective realities (Alexander 2016). The aforementioned clearly indicates that the data generated integrated both figures and words, thereby combining elements of the qualitative and quantitative approaches in order to provide a more comprehensive and complete understanding of the importance of incorporating social media into curriculum leadership and pedagogy (Creswell 2014). The exact exploratory sequential mixed-method as adopted for this study is illustrated in Figure 9.2.



Source: Adapted from Oosthuizen et al. (2019:73).

FIGURE 9.1: Graphic illustration of the mixed methods' research strategies.



Source: Adapted from Oosthuizen et al. (2019:74).

FIGURE 9.2: Graphic illustration of the exploratory sequential mixed methods' research design.

As can be discerned from Figure 9.2, two types of data (qualitative followed by quantitative) were collected and analysed following the same sequence (Creswell 2014). The population for the study were the secondary school management teams (SSMTs) from an education district in South Africa where learners came from communities characterised by a diversity of socio-economic backgrounds. Probability and non-probability sampling techniques were adopted with the former designed to generate quantitative data and thus being systematically executed ensuring that each and every sampled unit had an equal chance of being included and that the findings have external validity (Creswell 2014; Nieuwenhuis 2016). Noting that the sampling for the qualitative data collection is naturally non-probability and purposeful and does not select participants randomly as happens with the quantitative data collection process, the qualitative non-probability sampling technique adopted thus ensured that all participants were members of the SSMTs within their respective schools (Joubert, Hartell & Lombard 2016). As a result, a total sample size of 100 respondents took part in the study and completed the two sets of questionnaires (structured and unstructured questionnaires), which

were distributed to ensure that both the qualitative and quantitative data respondents completed them. The former questionnaire was focussed on generating qualitative data, while the latter was designed for gathering the quantitative type of data. As a result, the data generated not only had an objective ontology but also multiple subjective realities (Alexander 2016). The data generation instruments were first piloted with members of the SSMTs from a different district but in the same province prior to their full adoption in the main study to ensure their reliability and validity (Galusha 1997; Richardson 2015). Member checking was also adopted by asking colleagues in the school of professional studies to verify the data collection instruments for reliability and validity or trustworthiness (Babbie & Mouton 2010).

Results and discussion

The data analysis and presentation of findings for the qualitative section are herein reported beginning with a thematic approach. It is important to note that the quantitative section will adopt a descriptive analysis of the discussion of findings. The emerging themes from the qualitative data section thus inform the discussion as follows: forms of social media technology available to students in the 4IR, who curriculum leaders in the 4IR are and what curricular and pedagogical practices they lead in schools, the importance of curriculum leadership in the 4IR, how social media technology enhances improved learning in the 4IR and strategies for improved learner performance in the 4IR and through the social media technology.

Forms of social media technology available to students in the 4IR

In response to the question of listing examples of the social media technological platforms available to them in this era of the 4IR, many of the participants confirmed the views implicit in the literature review, especially Casey and Evans' (2011) assertion that learners in many secondary schools have WhatsApp, Facebook, Twitter, Instagram and YouTube as common platforms at their disposal. Many of the participants drawn from schools located in communities characterised by learners from diverse socio-economic backgrounds pointed out that in many schools in South Africa whether primary, secondary or tertiary, learners, be they in junior or high schools, are either on a WhatsApp, Facebook or YouTube platform, which they use to communicate with colleagues, family members, their educators or friends. While the majority of the participants could make this assertion about the experience of other learners, they drew predominantly from their own experiences of their social circles. Some participants also drew from their experiences with high schools in some affluent areas where donations for mobile devices had to be requested

from parents so that some of the learners could use them during the lockdown. These schools had some learners who did not have access to mobile devices such as smartphone in their homes and were therefore not able to access their lessons. Some participants further pointed that even some universities also had to organise devices for their students who claimed not to have devices to access learning materials during the lockdown. Drawing from some of these views, it sounds a bit problematic for one to make some of the aforementioned assertions or to simply accept them as facts from the participants, particularly given the existence of published literature that partly refutes some of these claims. The above findings also confirmed Bernoff (2008) and Dame's (2013) views that except in exceptional situations, in the modern day school setting, no learner is really without a mobile learning device as most have either a smartphone, a tablet, an iPad or a laptop, which they use for communication in one way or another. The aforementioned further dovetails with what Madge et al. (2009) claimed in their contention that the use of social media technology has become so fashionable that virtually all learners go to school without any communicative gadgets.

Who curriculum leaders in the 4IR are and what curricular and pedagogical practices they lead in schools

In their response to who the curriculum leaders are and what curriculum and pedagogical issues they lead in the 4IR in their institutions, many of the participants listed school superintendents, curriculum supervisors, school principals and subject heads of departments, senior educators and specialist subject advisers as typical examples. The participants claimed that these personnel have important roles to play in instructional leadership, curriculum reforms and curriculum leadership per se. The following arguments were presented as typical of some of their roles:

- **Participant 1 (Head of Department and member of the SMTs):** In the South African context, the role of school superintendents, school subject advisers and curriculum supervisors is almost equal to that played by representatives of the South African DoE through their education advisory services.
- **Participant 2 (Deputy school principal and SMT member):** Within the South African school context, senior educators and subject heads of departments also play an important curriculum leadership role and according to responses from members of the SSMTs, this is one opportunity classroom practitioners have to develop not only their curriculum leadership. Roles but also to demonstrate that virtually every classroom practitioner occupies a curriculum leadership role for the learners within their classrooms and by virtue of possessing highly valued and highly sought-after curriculum knowledge.

- **Participant 3 (SMT member and school principal):** Although curriculum leadership from senior figures in the secondary school curriculum is of paramount importance, many other positions and individuals in the secondary schools should also be encouraged to provide such leadership roles especially for particular tasks or of the hidden school curriculum to offer tacit learning experiences to some of the learners. For me, this implies capacity building or development to boost the school culture and image while benefitting the school community and also preparing such individuals for future more senior leadership opportunities.

Further responding to the question of what curriculum leaders need to lead in, a number of participants cited engendering a sense of purpose, influencing others towards achieving goals and making improvements in their practices and seeing that the curriculum is that which is translated from the national statements. Some of the participants cited the need for creating classroom WhatsApp and or Facebook working groups, creating student blogs, posting assignments on YouTube and showcasing student works on Instagram.

A good number of the participants pointed out that although it is somehow hard to believe, WhatsApp or Facebook groups can be used as learning tools for educator-learner interactive social groups. Further exploring the underlying purpose for social media modes of address, the participants were quick to point out that these apps facilitate communication, and, at their most basic level, offer effective communication because interlocutors have to respond to each other's messages. Given that at its best, education is nothing more than effective communication, social media apps can provide a channel through which educators can achieve faster and more seamless communication. In pursuit of this view, one SSMT member had this to say:

- **Participant 10:** It is important that classroom practitioners in today's educational world view Facebook and WhatsApp apps as means to an end rather than as ends in themselves.

Explaining their understanding of the educational values of the social media technological platforms, many members of the SSMT revealed that they view these apps as facilitators or an effective means of disseminating educational resources, content, notes, assignments and information to their students as part of blended learning initiatives.

Interventions for improved learner performance in the 4IR

Discussing the idea of possible strategies that educators can use to leverage Facebook, YouTube or WhatsApp social media platforms to enhance students' educational experiences in the 4IR, the following aspects were cited as the most possible strategic forms: using the group chat feature to create learning

and study groups and virtual classes for students. As examples, members of the SSMT cited students who are homesick or unable to get to classes as capable of being able to use this feature to connect with their classroom partners or parents. A further strategy cited by the SSMT members involved creating YouTube-based audio-visual lessons that can be sent directly to the students via the apps, which can be original lessons or simple audio-visual recordings of important classroom lessons that can be sent to students via the apps again in a manner consistent with the dictates of blended learning initiatives. Some participants argued that an interesting variation for this strategy involves creating video problems for students to solve or work on away from the classroom as this helps get them more interested in homework by creating a visual involvement. Sending graphic illustrations such as pictures or charts directly to students even when they are not in the classroom was cited as also going a long towards embellishing students' understanding of the taught content. Further to these interventions for improved learner performance in the 4IR participants also cited the following skills as essential for effective functioning in the era of the 4IR: creativity, a high level of emotional intelligence, analytical (critical) thinking and active learning with a growth mind set and judgement and decision-making. A further inquiry led to the participants pointing out the fundamentals for education, work and effective work in the 4IR; the following technological developments or tools drive the processes: high-speed mobile Internet, AI, automation and the use of big data analytics and cloud technology. This idea certainly resonates with Maloma's (2020) contention that the 4IR is a fusion of advances in AI, robotics, the IoT, genetic engineering and quantum computing. The same view also vindicates Lavopa and Delera (2021) assertion that because of the 4IR, ADP technologies are changing manufacturing and carrying implications for the future of industrial developments.

Findings from the quantitative section

The following key themes emerged following the data analysis process: major educational uses of the social media technology in the 4IR curriculum in general and curriculum leadership in particular, examples of social media platforms available for curriculum leadership in the 4IR and possible interventions to embellish curriculum leadership through the social media technology for the 4IR.

Major educational uses of the social media technology

A descriptive analysis of the quantitative data section reported herein shows that all the 100 respondents in the sample strongly supported the general integration of social media technology into the school curriculum of the 4IR.

TABLE 9.1: A rank order of respondents' views on social media use in the curriculum of the Fourth Industrial Revolution.

Rank order	Response	Total number of respondents	Percentage
1	To create WhatsApp or Facebook groups for classroom practice	42	42
2	For posting learners' audio-visual videos on YouTube	33	33
3	For showcasing the learners' work on Instagram	11	11
4	For helping learners realise the necessity to blog	9	9
5	Facebook, WhatsApp or YouTube social media platforms are also ideal for educators using the flipped classroom instrument to enable the posting of assignments, grades, comments, hand-outs or other documents and other learning resources on the group's wall or YouTube while learners peruse them before class or while working on their assignments	5	5
Total		**100**	**100**

A total of 75 of the 100 respondents (representing 75% of the sample) cited the following as the major social media technology in the school curriculum: the need to create WhatsApp or Facebook groups for classroom practice (42%) and the need for posting students' audio-visual aids on YouTube (33%), the issue of showcasing students' work on Instagram (cited by 11% of the respondents) and the need for helping students realise the importance of blogging (cited by 9% of respondents). Five per cent (5%) of the respondents cited Facebook, WhatsApp and YouTube social media platforms as ideal for educators using the flipped classroom as they enable the posting of assignments, feedback grades, comments, hand-outs or documents and other learning resources on the group's wall or YouTube while students are enabled to have sight of them before class or while working on their assignments. Asked to rank order these aspects in terms of their perceptions of what their educational utilities were, an overview of the responses of the 100 respondents is given in Table 9.1.

Taken together, the aforementioned illustrations clearly demonstrate the respondents' considered views on how important integrating social media technology into the school curriculum is in general and for curriculum leadership in particular.

Examples of social media forms available to students and curriculum leaders in the 4IR

All the 100 respondents were quick to point out that the following are the ideal examples of the social media technological platforms commonly available to them as curriculum leaders in schools of the 4IR: WhatsApp, Facebook, Twitter, Instagram and YouTube.

Seventy-three (73) respondents also explained that social media platforms are more often used for posting status updates, classroom assignments, announcements, photos and audio-visual aids, among other valuable activities in the 4IR learning environment. It was apparent in the respondents' views that educators improved and enhanced the effectiveness of the teaching and learning process by creating Facebook or WhatsApp class groups to upload assignments, make announcements, and remind their learners about upcoming deadlines. The respondents further noted that students' parents could also access these social media platforms to monitor their children's schooling careers. Using YouTube as an online video and social media sharing platform, as well as WhatsApp or Facebook as social media platforms, learners are able to view and learn while asking and answering questions in real-time. From the respondents' views, when learners are at home and wish to work on their homework, they can post questions to the group's wall which either their educator or fellow classmates can answer. As learning is effective through social interaction as noted by social constructivist theorists Vygotsky (1987) and De Valenzuela (2010), students can then learn from each other, and having them compare notes and answers to their questions, insights or experiences within a topic can expand their learning horizons.

The importance of curriculum leadership in the 4IR

In discussing the role of curriculum leadership and the significance of social media technology in the 4IR, 45% of respondents cited pedagogists' prodding for posting learner videos on YouTube. They argued that just like Facebook, YouTube offers excellent options for flipped classrooms, as students can see lessons and resources before entering the classroom. The respondents also noted that, like blogging, the learning material appeals to a wider academic audience. This is because learners are highly likely to perform at their very best while enjoying creating videos to express their creativity which leads to a deeper engagement with the course material. This view vindicates the assertion by Abe and Nickolas (2013) that classroom practitioners at any level can click on the education category within YouTube and find several subcategories such as university, science, business and engineering. It was pleasing to note that 52% of the respondents agreed that given that single pictures can be worth a thousand of words, it is unimaginable what a carefully crafted class Instagram feed relays to the students in that class. Implicit in this view is that an Instagram social media site can showcase the students' work by offering a platform for their aesthetic or artistic work. Asked to identify how best educators and learners can make use of Instagram, 37% of respondents argued in favour of posting items related to their favourite books

or historical figures as among the ways to showcase their accomplished work. Twenty respondents (20%) claimed that because many students love Instagram for reasons such as clarity of photos and the effects available to them, educators can create assignments that tap into such staff as photographic essays where students take photographs, upload them and add captions or even create campaigns for certain organisations or for their own classroom lessons.

Interventions to embellish curriculum leadership

Participants cited the following interventions as necessary for curriculum leadership and the creation of opportunities for students to blog in the school curriculum as a necessity, particularly during this 4IR era. Approximately 22% of respondents pointed out that they have observed their students' writing improving as they engage in it more. So rather than using traditional writing projects, blogs facilitate the creation of optimum opportunities for students to write and display their work on a large scale South African SMT, especially if the topics are topical. In addition, 20% also observed social media platforms like Twitter are designed, among other things, for reading, responding to specific situations, encouraging learners to converse via Twitter, posting their favourite quotes from a particular lesson and allowing them to interact with experts by tweeting questions or comments. Many academic institutions offer Twitter chat sessions with which students can interact, and according to these respondents, one of the most effective ways of using Twitter in teaching is as a reminder for students to complete assignments for a particular due date or notifying them of an imminent test or examination session for which they have studied a given scope. In pursuit of the above views, some respondents' views are summarised in Table 9.2.

TABLE 9.2: Intervention strategies for curriculum leaders to enable student blogging in the Fourth Industrial Revolution.

Intervention strategy	Number of respondents	Percentage
Having students reflect on some curricular aspects such as lessons or field trips	35	35
Documenting curricular research for larger projects such as reviewing books or audio-visual recordings	25	25
Asking students as part and parcel of their curricular reviews to illustrate their thoughts of the social media technological use in their school curriculum with images and audio-visuals	20	20
Having curricular activities where learners read each other's blog posts	12	12
Encouraging students to start a topical Twitter feed to post-class announcements and track information on a topic	8	8
Total	**100**	**100**

The respondents also noted that in the 4IR, these interventions have the potential to create a stronger sense of community and to help them discover their common experiences and to enable their work to be part of the greater World Wide Web. Furthermore, they also noted that apps such as blogging serve as excellent components of a discussion on aspects such as plagiarism, voice and writing style – a view that resonates with what Prensky (2001) and Uljens (2015) asserted just as WordPress, Blogger connecting educators to learners using unique themes and diary-style writing and that with access to the educators' posted links, the students' lessons and thoughts become more successful and comfortable with the educators online. About 8% of the respondents were agreed that in the same way as Facebook, Twitter also offers a quick way to post-class announcements and reminders as well as real-time information on class field trips and for tracking information on a topic. Fifteen respondents or 15% pointed out that as a result of following the Twitter feeds of experts in the field or the hashtags focussed on current world issues, students can learn about what is happening in the world around them. Listing examples of the social media sites capable of embellishing their curriculum leadership about 60 respondents cited Google, Skype, TeacherTube, LinkedIn, Labroots and ResearchGate as summarised in Table 9.3.

Twenty-one respondents (21%) argued that in addition to the great graphic illustration of themes and other salient features, Google+ takes educators to their students with circles that make managing virtual communication in the 4IR a cherished artwork. An example cited was that learners might wish to know more about a particular lesson because they may not have gotten it quite well the first time, and so by persuading them into a circle of their own with just the right tools to connect, they are able to get their path to a better understanding. Twenty respondents (20%) listed ResearchGate, claiming it resembles Labroots in that it also brings related scientists or members of similar subject groups together just as what Lave and Wenger (1998) regarded as the coming together of members of a community of practice for collaboration. As a result, curriculum leaders who have the temerity to champion the launch of ResearchGate as a social media platform and to employ it in classroom practice for the good of the teaching and learning

TABLE 9.3: A rank-ordered categorisation of the respondents' views on additional interventions.

Rank order	Response	Number of respondents	Percentage
1	Google+	21	21
2	ResearchGate	20	20
3	LinkedIn	18	18
4	Skype	15	15
5	TeacherTube	14	14
6	Labroots	12	12
Total	**6**	**100**	**100**

processes, consider themselves very initiative and treat themselves as a cut above the rest in terms of integrating the social media technology into the curriculum. As curriculum leaders, they thus certainly make a big difference in their mission. Using LinkedIn was cited by 18 respondents or 18% of the sample as one of the interventions for integrating social media into curriculum leadership. The respondents noted that while LinkedIn most often functions as a reliable site for professionals or social forum for employers to connect with applicants, it can also be used in pedagogy in helping students towards building their interconnectivity skills, and therefore, effective curriculum leaders need to ensure that it offers them initiatives for improved student performances. For the 18 respondents, the use of LinkedIn is important for getting educators and their students to stay in constant touch, and one way of doing so is by ensuring that it keeps the latter updated on topical educational affairs in their curriculum, and they can also use it to encourage student research; these are important facets in integrating the social media in curricular activities. It also helps students come to full terms with social realities and endless possibilities in their educational journey. The merits of using Skype were also cited by 15% of the respondents on the grounds that it connects students with colleagues anywhere in the world, which also implies they stay in touch with not only their educators but also broaden their worldviews. For these respondents, this also implies improving their virtual connections to enable effective cross-pollination of ideas or social facilitation in the school curriculum.

Fourteen respondents (14%) cited TeacherTube as one of the social media platforms arguing that if social media sites such as YouTube do not make the expected grade, it is important that educators and students turn to it (TeacherTube) given its dedication to all sorts of education programmes, particularly in the 4IR. The respondents further argued that they derive great pleasure in the realisation that the tabs for docs and audio are some of the more useful resources within it. For these respondents, it is the idea of TeacherTube and its tools that makes it so useful, and educators can thus use it to communicate with their students with no questions of whether this is within an educational format or not. Twelve respondents gave the example of Labroots as yet another social media platform that offers unlimited access to students to use a variety of documents and hundreds of scientific news feeds working with it as a social networking site catering predominantly for the curricular subjects as science, engineering and technical graphics. However, these respondents further noted that in this 4IR, the site can also be used by curriculum leaders in these fields to help their clients compare lesson notes or learn from each other or to stay connected with colleagues and peers in their educational fields. For these respondents, pulling one's students into the Labroots social media encounter gives them a cutting edge feel and insight into precious learning tools and access to vital knowledge.

Conclusion

The following conclusions were arrived at: the most commonly used social media sites that curriculum leaders need to integrate into the school curriculum during this 4IR are WhatsApp, Facebook, Twitter, Instagram and YouTube, and creating these social media sites can certainly enhance effective pedagogical practice. Posting the students' audio-visual work on YouTube goes a long way in buttressing curriculum leadership initiatives for the 4IR. Therefore, creating these social media platforms is one condition necessary for effective curriculum leadership meant to successfully transform the digital natives as part of their pedagogical practices in the 4IR. A further conclusion made is that adopting the media technology in the schools and classroom is important for educators who use the flipped classrooms for they can post assignments, grades, comments, hand-outs or other documents learning resources on the group's wall while providing access for their learners before class or while working on their assignments. The following were the recommendations made from the study: curriculum leaders are encouraged to ensure that they observe the value of creating opportunities for learners to blog in the school curriculum and realise that instead of clinging to the traditional practices of writing projects, using blogs is also an important process that fosters the creation of best opportunities for students to write and display their writing at a larger scale platform, especially for topical ideas. Further to this, curriculum leaders (cf. Masters 2002:30–31) also need to take cognisance of the fact that as Twitter is made not only for reading, but also for responding to particular situations, encouraging their learners or students to interact with others via it and posting their favourite quotations or a particular lesson and having them interact with experts by tweeting questions or comment should be encouraged as part of the school curriculum. For the 4IR, using social media platforms such as Twitter for teaching and announcing the imminence of tests or examinations, help learners to revise the scope for the work given and such initiatives go a long way in terms of boosting crucial aspects of curriculum leadership innovations.

Chapter 10

Exploring pedagogy within teacher education: Embracing the 4IR

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Abstract

In the era of the 4IR, technology has led to transformations in our daily lives. Teacher education institutions ought to equip their students with advanced pedagogy to succeed within the Fourth Industrial Revolution era. This study draws attention to the future of teacher education within South Africa by showcasing examples of pedagogy for the 4IR. This qualitative, interpretive study was conceptualised using the Technological Pedagogical Content Knowledge (TPACK) framework and was located at one university in KwaZulu-Natal, South Africa. Teacher educators completed a questionnaire, and based on an analysis of each questionnaire, a sample of participants were observed

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while lecturing to student teachers. Subsequently, a semi-structured interview schedule was used to interview the participants. Thematic coding and interpretive procedures were used to analyse the generated data. In this chapter, findings focussing on the use of blended learning, technology-based pedagogy and collaborative pedagogy are discussed. Moreover, this chapter engages with what enables and constrains participants when using these pedagogies. Additionally, this chapter discusses implications and recommendations for teacher education nationally and globally within the 4IR era.

Introduction

Education plays a significant role in preparing society for global changes. As we embrace the era of the Fourth Industrial Revolution (4IR), technology is used extensively in communities worldwide (Pyper 2017). Teachers must therefore become trained in using technology-based pedagogy effectively as they teach in the 4IR age to scaffold teaching and learning. More so now, within the era of the COVID-19 pandemic, technology-based online pedagogy is progressing rapidly at educational institutions. According to Murgatrotd (2020), to limit the spread of COVID-19, online pedagogy through the use of technology-based devices is contemplated as effective. Technology-based pedagogy signifies the effective integration of technology-based pedagogy and devices while teaching to support learning (Ertmer & Ottenbreit-Leftwich 2012).

Moreover, technology-based pedagogy is gradually replacing traditional pedagogy at educational institutions. Using ICT in educational contexts has become the catalyst for transforming education (Du Plessis 2013). Similarly, research (Naidoo & Govender 2019) suggests that the use of the Internet and the use of ICT could bring about changes in education. Also, through the use of technology-based pedagogy, students are provided with educational contexts that are relevant to their lives, thus inspiring effective teaching and learning and promoting student success (Qing 2003).

Problem statement and research question

Technology has led to transformations globally. As we embrace the 4IR, we need to establish if teacher training institutions are preparing their students with progressive pedagogy to flourish within the 4IR. This study draws attention to the future of teacher education within South Africa and reports on research that sought to explore lecturers' use of pedagogy for teacher education within the era of the 4IR. The main research question for this study focusses on:

1. What pedagogy do teacher education lecturers use within the era of the 4IR?

4IR

The 4IR signifies the integration of the virtual and physical domain to build a society that is connected globally. According to Schwab (2016), the 4IR era is a high-tech revolution whereby technology becomes rooted within communities and has transformed the way we work, live and relate to other members of society. The IoT, technology-based tools, AI, VR and robotics are transforming how people subsist in the era of the 4IR (Naidoo 2020). As we embark on embracing the 4IR, it is evident that technology will be essential in our lives. In the 4IR era, it is important to navigate societal and technological transformations (Naidoo & Singh-Pillay 2020). The 4IR affects the role that education plays in preparing students for working within a technological domain (Butler-Adam 2018) and influences the task that institutions of HE perform in supporting students for succeeding within a technological environment. Within traditional lecture rooms, students are located at desks surrounding one another. However, within the contemporary lecture room, we envisage a transformation and that real-time collaboration will be possible globally through the use of the Internet and technology-based pedagogy.

Additionally, to be successful within the 4IR, an important aspect to consider for progression would be technology development (Seck 2015). Technology development necessitates that students need to be made aware of and encouraged to learn by using technology-enabled pedagogy. Teaching and learning using technology-based tools enhance the development of technology within educational contexts. Technological changes have transformed educational contexts, and key knowledge and skills concerning the use of technology-based tools in teaching and learning are needed as we embrace the 4IR (Makgato 2019). As professionals working in the education sector, we need to welcome these changes, and we need to aim for proficiency when using technology-based pedagogy. Thus, there is a need to include these aspects within teacher education courses and modules that are being offered at HEIs.

Teacher education

Education policy and practice are being profoundly changed in South Africa. Teacher education institutions are required to comply with and embrace these changes. As we welcome the 4IR, additions to the DBE's CURRICULUM AND ASSESSMENT POLICY STATEMENTS within basic education, revisions and additions to teacher education curriculum entail a transformation in pedagogy. Teacher education is non-stop, and development that enhances teachers' pedagogy, promotes the acquiring of new information and advances skills that encourage students' learning is essential. Effective teacher education is

necessary for developing the progressively multifaceted skills students need to learn and understand to flourish within the 4IR and to support student attainment (Naidoo & Singh-Pillay 2020). According to Timperley (2011), teacher education often takes place in official surroundings, such as teacher training and development platforms, teaching and research communities and prescribed mentoring courses. However, teachers also acquire knowledge through informal collaborations and during peer interactions, planning sessions and teaching (Little 2012).

Teachers need to have in-depth knowledge of the curricula, profound content knowledge, practical pedagogy and a good understanding of their learners (Nind 2020). However, in South Africa, teachers' lack of computer skills has affected their use of technology-based tools and devices for teaching and learning negatively. Thus, a large number of teachers are guarded about changing their pedagogy to include technology-based tools and devices in their educational contexts (Stols et al. 2015). Nonetheless, numerous educational resources and websites are available to support teachers with effectively integrating technology-based pedagogy to scaffold students' learning and achievement (Pope & Mayorga 2019). Teachers need to consider engaging with these resources because research (Cheung & Slavin 2013) supports the view that student learning and performance improve through the use of technology-based pedagogy. As teacher knowledge, interaction and feedback are important to ensure that technology-based tools are used effectively (Qing 2003), teachers need to be supported with how to use technology-based pedagogy effectively within their educational contexts.

Technology-based pedagogy

Technology-based pedagogy implies the integration of technology-based tools, devices and resources in educational contexts aimed at encouraging teaching and learning. In this chapter, technology-based tools are technology instruments that are used to support teaching and learning; these include, among others, the interactive whiteboard, the computer, the overhead projector and the document camera. As discussed in this chapter, technology-based tools also include digital tools, for example, computers or portable devices, that function with audio, pictures, text and video to support learning and teaching (Peachey 2017).

Using technology-based pedagogy has increased as tools and devices become more widespread and affordable (Rasanen et al. 2019). To use technology-based pedagogy effectively, lecturers are required to choose the appropriate technology-based device to match the purpose of their instruction. This instruction ought to be centred on students' requirements. Thus,

technology-based tools that are used for teaching ought to be considered an important part of the teaching and learning process. There are various websites, education applications and software programmes that are available and may enhance technology-based pedagogy (Pope & Mayorga 2019). However, it is not an undemanding task for the lecturer to identify the best technology-based tool amidst the vast assortment that exists. The idea is to choose a device that is accessible to all students, and the selected device needs to advance teaching and learning. The lecturer's task is to encourage improvement within their educational contexts (Montrieux et al. 2015), and the lecturer needs to try technology-based pedagogy to attain success in the lecture room. Moreover, within the era of the 4IR, one relevant pedagogy to consider is blended learning.

Blended learning pedagogy

Blended learning is an example of pedagogy that incorporates the use of technology-based tools, platforms and resources within education contexts. It is a pedagogy that incorporates both traditional teaching and the integration of technology-based tools within teaching and learning (Lalima & Dangwal 2017). Blended learning merges online educational resources and applications with collaboration during F2F contact sessions. This pedagogy encourages students to learn using technology and online platforms in parallel with the contact mode of teaching and learning (Jong 2016). Thus, blended learning necessitates the presence of both the student and the lecturer.

The role of the lecturer and student is critical when considering the use of blended learning pedagogy. The lecturer is a guide or facilitator, and students play an interactive role. As the student and lecturer interact dynamically within the lecture room, this pedagogy requires a deep commitment from both the student and the lecturer. When using blended-learning pedagogy, the lecturer needs to guide and support students as they reflect, learn, solve problems and question using a student-centred approach (Jong 2016). Moreover, in the era of the 4IR, where technology plays an essential role in our lives, education is facing challenges (Fadzil et al. 2019). The blended learning approach is appropriate and supports the importance of embracing the 4IR and the use of technology-based pedagogy (Hains-Wesson & Tytler 2015).

Collaborative pedagogy

Students operating individually are capable of learning significantly; however, designing learning activities so that students are required to engage, share

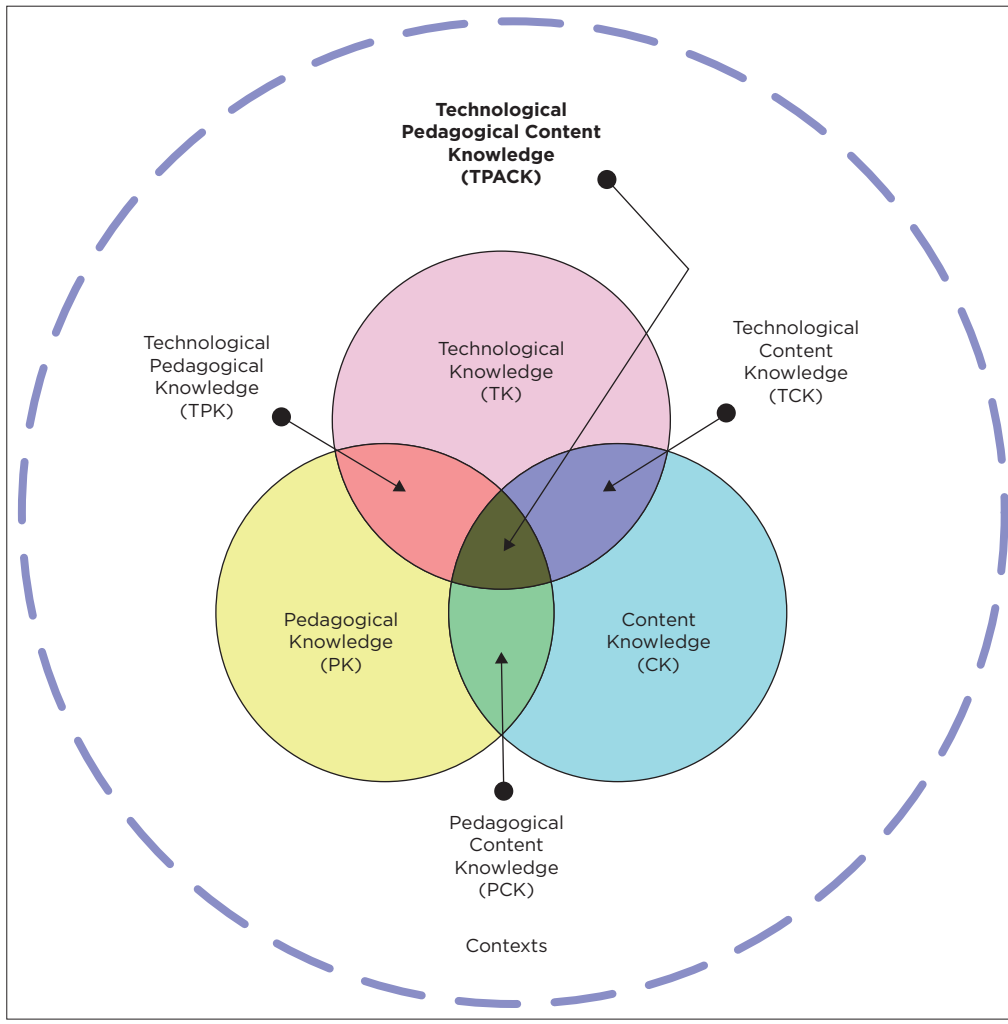
ideas, communicate and collaborate is an effective pedagogy. Kirschner, Paas and Kirschner (2009) maintained that learning independently becomes less effective than learning in a group as the intricacy of activities deepens. Thus, as students are exposed to more in-depth and challenging content, it is good to allow students to share ideas and collaborate, focussing on improving understanding and motivating active student participation. Collaborative pedagogy transfers the teaching emphasis from the lecturer to the students to promote and empower students' independence by offering them the responsibility and creativity for the learning process (Zhou, Chen & Chen 2019). Thus, as learning is a collaborative process (Lawson 2011), lecturers need to create a context that supports student engagement. Student engagement ought to incorporate more than just students working together; it ought to include effective teamwork with roles defined to ensure the success of the collaboration (Hernandez 2012).

Along similar lines, research (Domalewska 2014) supports the notion of encouraging the use of collaborative pedagogy when using technology-based pedagogy as collaboration provides the best benefits for students. Through the use of technology-based pedagogy and collaboration, students enhance their current knowledge and develop skills while fostering a relationship with their peers and their lecturer. Thus, collaborative pedagogy changes the teaching focus from the lecturer to the student to encourage student independence and enable students to become accountable when learning (Zhou et al. 2019). Also, by using technology-based pedagogy, lecturers are supported as they design lessons that encourage interactive student learning, which is effective and innovative (Ghavifekr & Rosdy 2015). To ensure the success of incorporating technology-based tools into lessons, lecturers need to know their content, have knowledge of pedagogy and have an understanding of technology. Thus, lecturers are required to possess adequate TPACK.

Technological pedagogical content knowledge framework

When using technology-based pedagogy, the lecturer must select the appropriate technology-based tool for proficient teaching and learning. To make this choice, the lecturer ought to have adequate TPACK. The TPACK framework is established on the basis that lecturing is complex and requires different types of interconnected information, as depicted in Figure 10.1.

The notion of the TPACK framework is established on a lecturer's proficiency when integrating technology-based devices and tools during the lecture to scaffold successful learning and teaching (Koh & Sing 2011). Shulman's (1987) ideas about teaching and learning were developed by



Source: Adapted from Koehler et al. (2013:3).

FIGURE 10.1: The Technological Pedagogical Content Knowledge framework.

Mishra and Koehler (2006). These ideas now encompassed the aspect of technological pedagogical knowledge. The link between this study and the ideas in the TPACK framework, as maintained by Mishra and Koehler (2006:63), includes an understanding of concepts and ideas being taught during the lecture as content knowledge. Pedagogical Knowledge refers to teaching these concepts and ideas to promote teaching, experience and learning. Understanding and integrating technology-based devices and tools in the lecture is is called "Technology Knowledge" (TK). The technology-based devices and tools used in this study included a document camera, an

overhead projector, a data projector, a laptop (personal computer), an interactive whiteboard and a smartphone. Information that is important for teaching is called pedagogical content knowledge. Technological content knowledge means knowing and understanding which tools and devices are appropriate for teaching and learning the mathematical concepts under focus.

To acknowledge the strengths and challenges of using technology-based tools, devices and pedagogy, it is important to acquire technological pedagogical knowledge. This knowledge provides both lecturers and students with a variety of approaches that encompass various learning styles within an educational context. Consequently, as technology-based pedagogic tools are being used within educational contexts (Franz & Hopper 2007), lecturer knowledge and active discussions are essential to ensure that these tools are used suitably. A lecturers' understanding and ability to select appropriate pedagogic tools are critical for efficiently integrating technology-based methods in a class (Niess 2005). Thus, this implies that lecturers using technology-based pedagogy efficiently within their educational contexts ought to possess adequate TPACK. Hence, this framework (TPACK) framed and supported the types of knowledge the participants implemented throughout their instruction. Moreover, this framework (TPACK) was used in this study to explore what enables and challenges lecturers when using blended learning and technology-based pedagogy within their educational contexts.

Methodological considerations

This interpretive, qualitative study, which sought to explore pedagogy used by lecturers in teacher education, showcases examples of pedagogy for the 4IR. Data were generated using questionnaires, lecture observations and semi-structured interviews.

Ethical issues

The participating university was informed of this study, and gatekeeper access and ethical clearance were acquired. An informed consent form clarifying the purpose of the study was given to all participants. In addition, the informed consent clarified all processes for the study. Also, participants were informed that they could leave the study at any time without prejudice. The participants were informed of the audio recording of all interviews. Participants provided permission for the audio recording of the interviews. Furthermore, pseudonyms were used to ensure each participant's confidentiality and anonymity. Each participant was named using the letter 'L' signifying 'lecturer' and a numeral assigned to each completed questionnaire.

Participants

The population for the study was lecturers[1] who lectured modules within teacher education at the participating university. For this study, 28 lecturers were invited, and 22 accepted the invite. Five lecturers were randomly selected to participate in the pilot study. A questionnaire, lecture observations and semi-structured interviews were used to generate data.

Pilot study

The pilot study ensured the trustworthiness of each research instrument and the research process. By administering each questionnaire, observing lectures and interviewing participants for the pilot study, the dependability of each research instrument improved as aspects of the questionnaire, observation schedule and interview were modified to a minor extent. For example, during the pilot study, some participants were unclear of responses to a few questions for the questionnaire. Additionally, some of the interview questions were not explicit. Subsequently, items on the questionnaire were revised to remove uncertainty. These revisions ensured that the questionnaire was straightforward. Thus, simple and clear language was used during each interview to improve the dependability of this instrument.

Main study

Questionnaire

For the main study, the questionnaire was distributed to 17[2] participating lecturers. The questionnaire entailed two sections; the first part of the questionnaire focussed on each participant's biographical details. The second section focussed on each participant's experience, knowledge and training for using technology-based pedagogy. Here it was essential to analyse the expertise each participant had concerning using technology-based pedagogic tools and each participant's knowledge and exposure to the ideas of the 4IR.

Although 17 participants were invited to complete the questionnaires, 13 out of 17 participants handed in their completed questionnaire (L1–13). Based on an analysis of the completed questionnaires, seven participants were observed lecturing (L1, L3, L4, L5, L6, L9, L11) because of their responses focussing on the types of pedagogy they indicated they used when lecturing. Subsequently, these seven lecturers were interviewed.

1. The terms participants and lecturers are used synonymously in this chapter.

2. A total of 28 lecturers were invited to participate, and 22 lecturers responded positively to the invite. Of the 22 lecturers who agreed to participate in the study, for the pilot study, five participants participated. For the main study, 17 participants participated.

Observations

Non-participant observation methods were used; the researchers did not interact with the lecturer or students during each observation. One lecture for each of the seven participants was observed. The duration of each lecture was one period of 45 minutes. An observation schedule was used during each lecture observation. The observation schedule focussed on the styles of pedagogy used by the participants. The observation schedule also focussed on the interactions between the lecturer and students during the lecture. Additionally, field notes were made during each observation. All observations were analysed before the interview.

Semi-structured interviews

Each of the seven observed participants was interviewed after their lecture observation schedules were analysed. Each interview was audiotaped and transcribed. Thereafter, each transcript was perused by the respective participant. The participants verified their transcripts for validity and accuracy. During each semi-structured interview, participants' responses were probed to acquire clarity for each lecture observation. The duration of each interview was roughly 45 minutes. For each interview, the time and venue most fitting for the participant were selected. Common questions were asked at the beginning of each interview to make the participants comfortable. After that, more explicit questions were asked, focussing on each participant's responses to the questionnaire and particular moments observed during their lecture observations.

Data analysis

Each questionnaire was analysed whereby responses were manually entered onto a spreadsheet; codes were created and assigned. To analyse the generated data, three stages of coding were used. Firstly, open coding was used to analyse data to reveal unexpected perceptions of participants concentrating on their use of different kinds of pedagogy and their views on the 4IR. It was also important to interrogate the participants' opinions concerning their TPACK. Secondly, data were carefully studied using a list of predicted codes and themes revolving around each participant's response. Finally, the participant's responses were compared to examine differences and similarities. Each response and its link to the TPACK framework were analysed.

In response to the main research question for this study, a qualitative interpretive in-depth analysis of the completed questionnaires revealed that seven participants used various technology-based collaborative pedagogies when lecturing. For example, the participants used a combination of online discussion forums, Moodle,[3] smartphone technology, interactive whiteboards,

3. Moodle is a license free open source course/learning management system (LMS) used at the participating university.

MS PowerPoint presentations, overhead projectors (OHPs), video clips and collaborative pedagogy. Consequently, seven participants were purposively selected for lecture observations. The lecture observations were summarised and were examined to determine if there were any connections or patterns. The synthesised views were coded by acknowledging critical concepts of the conceptual framework within which the study was embedded. Hence, observations and their relationship with the TPACK framework were analysed.

Following the observations, the seven lecturers participated in individual interviews. The purpose of these semi-structured interviews was to probe the participants concerning their choice of pedagogy. A qualitative analysis of data was conducted. After the transcription of the interview data, data were examined to become familiar with the data. Subsequently, coding and labelling of the text ensued. The coding was beneficial in identifying themes. These themes were reviewed by acknowledging the conceptual framework within which the study was embedded. Through this qualitative analysis, the themes that were generated are presented and discussed in the subsequent findings and discussion sections.

Findings

Questionnaire

All analysed questionnaires elicited important information about the participants' use of different pedagogy when lecturing. Table 10.1 exhibits the types of pedagogy used by the participants. Table 10.1 represents examples provided by the seven participants who were subsequently observed and interviewed.

As was evident, the participants used a range of types of pedagogy. Data generated from the selected observations of the participants are presented in the section that follows.

Observations

Seven participants were selected for lecture observations based on an analysis of the questionnaires completed. During the observed lectures, the participating lecturers used various strategies to promote teaching and learning. The selected extracts from the observations that follow have been purposefully chosen vignettes to demonstrate the diverse pedagogic approaches lecturers used to embrace the 4IR.

In the vignette (Figure 10.2), L1 used role play and simulations during the lecture.

TABLE 10.1: Examples of types of pedagogies used by the participating lecturers.

Participating lecturer	Examples of types of technology-based pedagogies used	Examples of types of collaborative pedagogies used
L1	• Online discussion forums[4] • Moodle • Interactive whiteboard • Overhead projector and transparencies[5] • Video clips	• Simulations and role play[6] • Small-group discussions
L3	• Moodle • Smartphones (WhatsApp[7] messaging)	• Peer teaching • Small-group discussions
L4	• Moodle • Overhead projector • Smartphones (WhatsApp messaging)	• Think-Pair-Share Strategy • Peer editing • Small-group discussions
L5	• Moodle • Document camera • MS PowerPoint presentation • Video clips	• Small-group discussions • Peer teaching • Simulations
L6	• Moodle • Overhead projector • MS PowerPoint presentation • Video clips	• Peer teaching • Small-group discussions
L9	• Moodle • Online discussion forums • MS PowerPoint presentation • Video clips • Interactive whiteboard	• Think-Pair-Share strategy • Jigsaw strategy • Small-group discussions
L11	• Moodle • Overhead projector • MS PowerPoint presentation • Smart phones (WhatsApp messaging)	• Peer assessment/editing • Peer teaching • Small-group discussion

4. Online discussion forums can be used to help students to review material prior to an assessment or engage students in discussion of module content before coming to the lecture. This type of discussion forum may also allow students the opportunity to reflect on content that they have engaged with outside of the lecture.

5. By using a light, an OHP projects an image that is enlarged on a whiteboard/screen. The image source is a transparency which is a sheet of transparent material. The transparency is placed on the OHP and projected to the class.

6. Within simulations, students are asked to assume roles as they work within a problem-solving group.

7. WhatsApp is a free messenger application that allows users to use the Internet to communicate. This communication is done through sending messages, images, audio and videos.

One student stands up at the front of the lecture room, and her peers (*n* = ±50) are attentively watching what transpires. The student at the front assumes the role of a Grade 9 science teacher and proceeds with explaining the concept of **chemical reactions** while using the white board and transparencies. The rest of the students in the lecture room assume the role of Grade 9 learners. The 'teacher' proceeds to complete a small demonstration of the reaction that occurs between two household ingredients (vinegar and baking soda for a homemade chemical volcano, she also added orange food colouring to the baking soda so that the volcano looked realistic). The 'teacher' goes on to explain the processes that occur during chemical reactions, that is, materials are transformed with new physical and chemical properties. She goes on to explain that **reactants** are materials we start with, and the name given to new materials is **products**. The 'Grade 9' learners discussed what they had seen and asked the 'teacher' for clarification of the reactions that occurred. The 'Grade 9 learners' worked in small groups (five to seven students) to discuss the demonstration and attempt to identify the chemical formula of each reactant and the **final product**. The lesson progresses where the 'teacher' illustrates how **chemical reaction equations** are written and how these equations are **balanced**. The teacher uses the **chemical formula** of the two household ingredients that reacted in the demonstration. The 'teacher' uses the whiteboard to support her explanations. The lesson proceeds with further examples of writing and balancing chemical reactions. Activities are assigned to the 'Grade 9' class before the end of the lecture. [This simulation/role play and physical demonstration encouraged active engagement and participation. There was evidence of teamwork and the students responded to questions actively and participated by asking questions to clarify their understanding of the observed chemical reactions.]

FIGURE 10.2: Vignette: L1 observation: Focussing on simulations[8] and role play.[9]

The lecturer starts with a discussion focusing on **'Buildings and bridges'** with students (*n* = ±40). A **MS PowerPoint presentation** is used to show three pictures of different ways that bridges may fail. Students are asked to **Think** about what went wrong in each of the three cases. After five minute, the students are asked to **Pair** up with a peer and describe their views of what went wrong in each of the three pictures shown. Each pair of students was asked to discuss how these failures in bridge building could be prevented in the future building of bridges. After 10 minutes, a selection of pairs of students were asked to **Share** with the entire class/lecture group their paired discussions and their own ideas on what went wrong in the three pictures and how this could be prevented in the future building of bridges. [The Think-Pair-Share strategy in this lecture initiated discussion, collaboration and active participation.]

FIGURE 10.3: Vignette: L4 observation[10]: Focussing on the think-pair-share strategy.

Based on the observation for L1, simulations, role play and demonstrations created a platform for active participation and collaboration in the lecture under focus. Moreover, the use of technology-based pedagogy in this lecture supported the discussions in the lecture room.

In the vignette that follows (Figure 10.3), L4 used a collaborative pedagogy called 'Think-Pair-Share' together with a technology-based device or tool to scaffold learning and teaching during the lecture.

8. In the vignette that has been included of the observed lecture for L1, the lecture was based on a science third-year methodology lecture where one (1) student assumed the role of a Grade 9 Science teacher and the rest of the students assumed the role of Grade 9 Science learners.

9. Within the vignettes, the authors/researchers have written words in square brackets. This has been done to ensure that sentences flow to assist with the reader's understanding.

10. In the vignette that has been included of the observed lecture for L4, the lecture was based on a technology second-year methodology lecture where the lecturer was discussing the topic 'Buildings and bridges'm which is taught in the Grade 8 Technology curriculum.

Based on L4's observation, the use of the technology-based pedagogy supported the collaboration and discussions during the lecture. Students actively participated and worked as effective teams to add to the discussions during the lecture. It is evident from this vignette that the lecturer made students aware of technology-enabled learning. Through the use of technology, students were encouraged to learn by using technology-enabled pedagogy. These skills are important for succeeding in the 4IR.

As reflected in Figure 10.4, L9 used a collaborative pedagogy called 'the Jigsaw strategy' in the vignette. This strategy was used in combination with technology-based tools.

What was evident in this lecture (Figure 10.4) was that all students were actively involved. Through the use of technology and research, they had vital information to discuss to ensure that the Jigsaw (Topic: 'Equations and inequalities') was completed and understood. The use of Moodle and discussion forums allowed the lecture to proceed without complications as all issues were addressed before the lecture by using technology-based tools. The use of technology-enabled pedagogy in this vignette shows the lecturer and students embracing the 4IR in the lecture room under focus. In the 4IR era, it is essential to exhibit how technology-enabled pedagogy scaffolds the teaching and learning process.

As captured in Figure 10.5, L11 used collaboration, peer assessment/peer editing during the lecture in the vignette.

The lecturer started with a discussion and revision of **'Equations and inequalities'** with the students (n = ±60), using a **MS PowerPoint presentation**. The lecturer used the **interactive whiteboard** to discuss and illustrate examples of different concepts within equations and inequalities. Small groups of students (seven to eight) were asked to explain **subtopics** within the topic further with examples while explaining problem-solving techniques using a **step-by-step process.** The groups used a combination of the interactive whiteboard, MS PowerPoint presentations and **video clips** as they discussed each subtopic assigned to the **expert groups**. [Prior to the lecture, the lecturer used discussion forums via **Moodle** to allocate group members to expert groups, the groups were asked to conduct research on specific subtopics so that they could expertly discuss the concepts and explain the sub-topics using examples and problem-solving within the subtopics. The groups were allocated the following subtopics: Group A: 'Completing the square'; Group B: 'Quadratic formula'; Group C: 'Substitution'; Group D: 'Finding the equation'; Group E: 'Nature of routes'; Group F: 'Quadratic inequalities'; and Group G: 'Simultaneous equations'. So essentially, each group was asked to research and become experts in each part of this **topic (Jigsaw puzzle)** so that eventually once all groups discussed their **subtopics (different parts of the Jigsaw puzzle)** then the entire group would have the necessary information to understand the **complete topic (complete Jigsaw puzzle)**. For the lecture that was observed, only four of the seven groups managed to complete their parts of the topic (Jigsaw puzzle). The remaining groups would complete their subtopics at the next lecture. This lecture exhibited active participation and collaboration between the students and the lecturer; the lecturer often came in during the expert discussions to add clarity or probe responses during the problem-solving process and explanations. The lecturer also facilitated the Jigsaw strategy used during this lecture.]

FIGURE 10.4: Vignette: L9 observation[11]: Focussing on the Jigsaw strategy.

11. In the vignette that has been included of the observed lecture for L9, the lecture was based on a mathematics fourth-year methodology lecture where the lecturer was discussing the topic 'Equations and inequalities' which is taught in the Grade 11 mathematics CAPS curriculum.

At the beginning of the lecture, each student (n = ±70) submitted a draft task to the lecturer. The lecturer continued with her lecture. Around 20 minutes into the lecture, the lecturer handed out the submitted **draft tasks** randomly to students to provide feedback. [This was agreed upon by all students when the task was initially allocated. To assist with anonymity, the students did not write their names on their draft tasks; they wrote down their student numbers. Based on the observation of the students engagement with the peer assessment/editing, students worked collaboratively with each other and the lecturer. They often raised a hand to ask a question to clarify and enhance understanding of the aim of the peer assessment/peer editing. Approximately 15 minutes of working on providing written feedback to their peers, the students handed back their attempts at peer assessment/peer editing to the lecturer. Before leaving the lecture room, all students received their own tasks. In this way, all students had the opportunity to work with the feedback given by their peers during peer assessment/editing before handing in their work for final assessment by the lecturer.]

FIGURE 10.5: Vignette: L11 observation[12]: Focussing on peer assessment/editing.

In this lecture (Figure 10.5), peer assessment or peer editing encompassed a method in which students read and commented on their peers' written tasks. This was effective as students were collaboratively interacting with each other and the lecturer while working on peer assessing/editing of the draft tasks.

Interviews

All the participants appreciated the use of blended learning, technology-based pedagogy and collaborative pedagogy to embrace the 4IR and save time during the lecture. These notions are supported by the interview transcripts that follow.

Blended learning

The participants used blended learning to demonstrate critical aspects of the content they were lecturing. The use of blending learning saved time during the lecture, encouraged active student interaction and supported discussions during lectures and online discussions. These notions are evident in the following interview excerpts:

> '[*U*]sing videos in class that show science experiments work [...] leads to discussion [...] if there are problems with technology during the lecture [...] we have load shedding[13] sometimes [...] or the Internet is not working [...] this affects my teaching and my lectures [...] Sometimes, students view videos before coming to class [...] we have more time to discuss the experiments in the lecture [...].' (Study participant, L1, date unspecified)

> 'Moodle is good [...] send instant emails to students [...] need to work with technology [...] it is beneficial [...] I upload video clips [...] students watch before

12. In Figure 10.5, this vignette has been included for the observed lecture for L11. This lecture was based on a BEd Honours lecture where the lecturer was discussing feedback on the first draft of a task that was submitted.

13. In South Africa, load shedding is the planned interruption of an electricity supply to avoid excessive load on the generating plant. A time schedule (planner) of all the stages of load shedding per province, city, town and suburb of load shedding times is available to all South Africa citizens.

> […] class […] prepared for the lecture […] have our best discussions after they view videos […].' (Study participant, L5, date unspecified)
>
> '[*W*]ith maths […] online discussions work […] students send queries and equations that are challenging […] whole class gets involved […] we clarify the queries by solving step by step using the board […] a good mix of traditional and online teaching […] the class enjoys working this way […] more productive […] engaging […].' (Study participant, L9, date unspecified)
>
> 'I use WhatsApp and Moodle to communicate […] my students are teachers […] sometimes […] difficult for them […] respond to emails […] quick message using […] cell phone works […] need to work with technology […] everything involves technology […] they already come prepared […] we engage in online discussions before the lecture […] saves time […] more time for discussion in class […].' (Study participant, L11, date unspecified)

As was evident, the participants used blended learning to save time in class, clarify misconceptions and communicate with students. The use of blended learning is a necessary approach to consider in the era of the 4IR. As is evident from the preceding transcript excerpts, blended learning encouraged students to learn using online platforms and technology-based devices and tools. This learning occurred concurrently with traditional teaching and learning. The use of blended learning also provided students with more time to reflect on what was taught or what would be taught in subsequent lessons. Lecture time was used for discussing challenges and misunderstandings. The participants did indicate that if there were issues with access to technology-based tools during the lecture because of load shedding or unstable network connections, this caused challenges during the lecture.

Technology-based pedagogy

The use of technology-based pedagogy was widespread. The lecturers used technology to communicate with students, scaffold teaching and learning, maintain students' interest and stimulate collaboration and discussion in the lecture room. These notions are supported by the interview excerpts that follow:

> '[*S*]ending WhatsApp messages […] effective […] the students […] always on their phone […] easy to communicate […] talk about deadlines […] clarify misunderstandings […] new way of teaching and learning […] easier than waiting for the following lecture […] technology supports teaching and learning […].' (Study participant, L3, date unspecified)
>
> '[*U*]se […] MS PowerPoint presentations […] technology is useful […] show students more […] better than writing […] board […] the way I was taught […] the presentations also interest the students […] they want to see and want to learn […] if we do not have electricity during load shedding, this is a problem […] lots of time […] spent on […] writing on the chalkboard […] which means less discussion […].' (Study participant, L6, date unspecified)

> '[*S*]ometimes [...] time-consuming [...] challenging to draw complex diagrams [...] use GeoGebra[14] [...] help [...] students see [...] complex diagrams [...] we rotate and transform [...] diagrams [...] to promote understanding [...] technology [...] enhances my teaching [...] can reduce and enlarge figures [...] students see scale drawings [...] technology has endless potential for maths [...].' (Study participant, L9, date unspecified)

As was evident, technology-based pedagogy enhanced teaching and learning in the lectures under focus. The participants included technology-based tools and devices in the teaching and learning process. This signified that the participants implemented notions of the 4IR in their contexts. However, the challenge of load shedding was also noted. Not having electricity to use technology-based pedagogy increased teaching time and reduced lecture time for discussion and collaboration.

☐ Collaborative pedagogy

The participants valued the use of collaborative pedagogy. The participants indicated that collaborative pedagogy was necessary to share ideas, clarify ideas, construct new knowledge and investigate further. The use of collaboration in the lecture room led to interesting discussions and debates. These notions are evident in the interview excerpts that follow:

> '[*O*]ften ask students to research [...] in advance [...] when they come to class [...] use peer teaching [...] students tend to discuss what they studied [...] teaching each other [...] there are lots of discussions [...] knowledge [...] more meaningful [...] through discussion [...] new knowledge emerges [...] sometimes [...] students forget to do [...] research [...] this is a problem [...].' (Study participant, L3, date unspecified)

> '[*S*]cience involves discussions and sharing ideas [...] use group discussions to support my lecturing [...] these discussions bring valuable knowledge [...] discussions are important to clarify and investigate [...].' (Study participant, L1, date unspecified)

> '[*M*]y Think-Pair-Share method works [...] my students share ideas and talk more [...] feel valued [...] feel they have something to contribute [...] about their existing ideas [...] and constructing new ideas [...].' (Study participant, L4, date unspecified)

> 'Jigsaw strategy encourages discussion [...] collaboration [...] students participate more [...] lecture is robust and engaging [...] sometimes not all students come prepared [...] this is a challenge [...].' (Study participant, L9, date unspecified)

As was evident, the use of collaborative pedagogy added value to the lecture. Students constructed new knowledge and ideas after interacting with their peers and lecturer. However, the challenge occurred when students arrived

14. GeoGebra is an interactive mathematical software programme for the teaching and learning of mathematics and science from primary school to university level.

unprepared to lectures, without the necessary information to share ideas and engage in discussions.

Discussion

The analysis of the qualitative findings provides evidence of the types of pedagogy used by the participating lecturers to embrace 4IR. The findings demonstrated that the participants used a combination of blended learning, technology-based and collaborative pedagogy within teacher education. The notions of the TPACK framework were evident in the study under focus. The participants were proficient in using technology-based resources and integrated technology effectively (Koh & Sing 2011) within the lecture rooms under discussion.

This finding resonates with research (Niess 2005), which has maintained that a lecturers' knowledge and ability to select appropriate educational tools are essential for efficiently integrating technology-based pedagogy within their educational contexts. The choice of pedagogy used by lecturers in this study was interactive and supported collaboration and participation in the lecture room and outside the lecture room. For example, the Think-Pair-Share strategy (see Figure 10.3) acknowledged that learning is a shared process (Lawson 2011), and the lecturer under focus created a context that supported student engagement. Moreover, as evident in the lecture focussing on simulations and role-playing (see Figure 10.2), the lecture was captivating and imaginative. The lecturer created an interactive approach to motivate collaboration within the lecture room (Howes & Cruz 2009). Previous studies in science education (Fadzil et al. 2019) have shown that a factor that influences students to opt out of registering for science subjects could be because of students perceiving science as challenging to learn as compared to other subjects. Students also tend to become demotivated because of the high failure rate and low grades; thus, constructing collaborative and stimulating lectures could assist in motivating students to succeed in science, as was the case in this study (see Figure 10.2).

Also, the peer editing/assessment (see Figure 10.5) was an effective collaborative strategy to use in the lecture under focus; the lecturer moved the teaching emphasis to the students to promote and empower their individuality by offering them accountability and innovativeness for the learning process (Zhou et al. 2019). Other more common examples of collaborative pedagogies, such as small-group discussions and peer teaching, also introduced a shared and interactive lecture context. The Jigsaw strategy (see Figure 10.4) exhibited student interaction and collaboration, where each team member had an explicit role to play to ensure the success of the teamwork (Hernandez 2012). This showed that the lecturer could merge various knowledge sources (content, pedagogical,

technology, pedagogical content and technological content) to ensure effective teaching and learning emerged. However, a challenge with this pedagogy could arise when students are not prepared to participate actively within the lecture.

The findings of this study also exhibited that students welcomed the notion of collaborative learning and were interested in the technology-based resources used. For teacher education in the 4IR era, this is an important finding for establishing what pedagogy ought to be used for scaffolding learning and teaching. The findings of the study under focus show that a large number of students prepared for lectures in advance, and they were ready to share and construct new knowledge with each other. Thus, if lecturers know what pedagogies are beneficial within teacher education, this will contribute to positive student performance and throughput.

Conclusion

In the era of the 4IR, the study aimed to explore pedagogy used by teacher education lecturers. This qualitative study was conducted at one HE institution in the province of KwaZulu-Natal, South Africa. This interpretive study involved the completion of a questionnaire by participating lecturers. In addition, these participants were observed lecturing, and they were subsequently interviewed. Based on a qualitative, interpretive analysis of the generated data, three main themes were identified. These themes focussed on the pedagogy used by lecturers in teacher education as they embraced the 4IR. The themes of blended learning, technology-based pedagogy and collaborative pedagogy were identified.

Furthermore, from the study's findings, it is evident that in a contemporary lecture room, as technology becomes more accessible and if the TPACK theoretical framework is incorporated as a practical framing, lecturers will seek to participate in beneficial pedagogy to improve student learning. From these findings, it can be concluded that it is essential to use a combination of traditional (collaborative) and new (technology-based and blended learning) pedagogy within teacher education as we embrace the 4IR. The findings of this study demonstrated that constructive collaboration between students, their peers and their lecturers could positively influence the teaching and learning outcomes of teacher education. However, for both the students and the lecturers in this study, the availability of technology-based resources was essential to achieve the learning outcomes.

This study has provided new perceptions regarding the pedagogy used in teacher education. It is recommended that further studies on a larger scale for exploring pedagogy used by teacher education lecturers in the era of the 4IR are necessary. Opportunities for further research could comprise similar

research studies involving different universities from the various provinces of South Africa. Comparable studies could be conducted at universities globally. Generating data on a large scale may offer further prospects for additional qualitative interpretation and analysis. Other quantitative research in the field could also be explored nationally and globally. These studies would be an advantage for promoting knowledge in this field, nationally and internationally.

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Chapter 11

The 4IR and teacher education in South Africa: Prospects for new imaginaries

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Abstract

In this final chapter, we attempt to synthesise the key themes emerging from the research reported in the book. Based on the identified themes that were developed variously by the authors who contributed chapters to this book, we specifically attempt to develop a model that can be used both as an analytical and evaluative tool to assess the opportunities and challenges currently being faced by universities in attempts to integrate aspects of the 4IR across the areas of curriculum, pedagogy, research and aspects of professional development. The chapter provides specific recommendations related to mitigated major barriers to the integration of the 4IR in teacher education in South Africa. It argues specifically for the development of knowledge

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ecosystems as a basis for the preparation of teachers around the areas of research, curriculum, teaching and learning and school-based training.

Introduction

There appears to be a resounding cautious optimism expressed across the chapters of this book about the prospects of integrating the Fourth Industrial Revolution (4IR) into teacher education in South African universities. That the 4IR is set to occupy the minds of academics in the coming decades cannot be disputed. Equally, multiple opportunities for driving improvements in learning are identified. The future of teacher education is expected to shift from lecture room synchronous encounters to isolated SDL in socio-economically diverse remote contexts. In a sense, this shift has already begun, thanks to the ongoing pandemic, which has necessitated the closure of universities and the utilisation of online teaching and learning modalities. The purpose of this chapter is to provide a summary of the key findings from the different chapters, to provide a synthesis of the major themes emerging from the chapters and to attempt a modelling of the key dimensions worth considering in efforts to integrate the 4IR into instructional curricula in teacher education departments in South Africa. Our analysis of the work covered in this book suggests that there are seven themes which we shall focus on in this final chapter. As highlighted in Chapter 1, these include the challenge of social justice in the context of the 4IR, the centrality of SDL, the IoT and social presence, teacher efficacy in the 4IR, Teacher technological literacy and readiness for 4IR uptake, pedagogical readiness and preparedness in the 4IR and the prospects for curricula transformation. These themes will be discussed both in relation to a need to identify key principles and strategies for integrating the 4IR in teacher education and also in terms of isolating the major challenges and impediments in the process. Together, these ideas will be redeveloped into a framework for integrating the 4IR in teacher education which we hope could act as some basis for new imaginaries. Specifically, we propose the adoption of the idea of knowledge ecosystems to help shape and direct teacher education and preparation.

The 4IR in teacher education: Emerging themes

We distilled seven themes across the chapters of this book. Some of these were cross cutting, while others were discipline specific. We start with the more cross cutting themes.

Social justice and the 4IR

The notion of social justice is a particularly pertinent one in education broadly and in teacher education in South Africa more specifically (Fraser 2008).

Set within the disciplines of politics and philosophy, its applications transcend multiple fields of policy, politics, economics, education and health amongst many more. The concept is a response to endemic injustices that pervade humanity, largely because of established power matrices that have defined human existence and relationships since time immemorial. In Aristotelean times, for example, the concept of society was viewed in terms of free people and slaves who were owned by the free people and who thus could not exercise their free will and had no legal rights. Interestingly, concern with such forms of blatant inequalities increased in strength during the early industrial revolutions as attempts were made to create more egalitarian societies and reduce the exploitation of the poor and marginalised people (Pyakurel 2021). The key concern was with the unequal distribution of wealth, property and resources which inevitably led to widely differentiated access to opportunities between people of different classes.

Although the concept is defined variously, its key focus is the creation of a fairer society, understood as one in which:

- Different socio-economic groups have equal access to the resources through which opportunities are created. In South Africa, where wealth differentials are so wide, large segments of society do not have the financial means to own the usually expensive technologies of learning. In addition, even if such technologies were allocated to the poorest schools, the geo-spatial distribution of infrastructure that supports learning technologies in poor and marginalised communities would render such provisions ineffectively or inefficiently utilisable. Such schools often do not have the capacity for proper maintenance and safe keeping frequently resulting in loss of equipment and in disuse.
- People from different socio-economic groups are provided with differentiated resources to increase the opportunities of all to achieve equal outcomes.

In Chapter 2, Krishnannair and Krishnannair highlighted the aspect of social justice and advocated extending the Bourdieusian notion of PH for it to be incorporated into the field of mathematics, to form the new MPH. For them, that places social justice at the centre of MP in the 4IR.

The centrality of self-directed learning

The concept of SDL is associated with individual students taking the initiative with or without the help of others. Such initiatives may happen in formal and informal settings. For example, in informal settings, the person who is inspired to learn may engage with Wikipedia, video tutorials and YouTube. Likewise, this happens in formal settings such as education institutions. For both settings, the learner is in full control as they diagnose their 'learning needs, formulating learning goals, identifying human and material resources for learning [and]

choosing and implementing appropriate learning strategies and evaluating learning outcomes' (Manning 2007:104). The 4IR and its various advanced technology allow for self-directed multimodal learning. Multimodal learning involves the use of these various technological advancements in teaching and learning. In Chapter 3 of this book, Olivier has engaged on the issues of self-directed and multimodality in HE with depth. He argues that traditional teaching and learning have viewed the teacher as an authoritative holder and giver of knowledge and the learner as an acquirer of that knowledge. In the traditional role, teachers would share knowledge with students on a particular topic through lessons that build on the learners' prior knowledge and direct them towards a deeper understanding of the subject. Olivier argues that focus on self-directed multimodal learning implies the shifting role of a teacher and the move to student-centred learning. He further argues that the role of a teacher in the student-centred approach involves but not limited to:

- guiding learners to reach a higher level of SDL
- promote cooperative learning
- promote problem-based learning
- the IoT and social presence.

Penprase (2018) argued that if teachers wish to be still useful and relevant in the self-directed digital era, they should aim to equip students with sets of new skills including, for example, creativity, collaboration, communication, critical thinking and continuous learning. For effective equipping of the learners with the 5Cs, they should also thrive to be technology oriented. Although this might be the case, Maringe and Chiramba in Chapter 1 concluded that the context of teacher education in South Africa has a serious shortage of resources to an extent that teachers lose the opportunity of engaging with deep learning required for equipping themselves for teaching and learning in the 4IR era.

The Internet of Things and social presence

Among the technological advances in the 4IR era, the IoT stands out prominently. In Chapter 1, Maringe and Chiramba listed the most common advances in technology to include AI, robotics, blockchain technology, quantum computing, nanotechnology and IoT. IoT involves transferring of 'data over a network without the involvement of human-to-human or human-to-computer interaction' (Gubbi et al. 2013:16480). In another definition, Hinojo-Lucena et al. (2019) postulated that IoT involves physical objects that are connected to the Internet which collect and exchange data in real time. Just like any other technological advancements, IoT has also dominated education sectors. Its benefits include remote sharing of knowledge, how to communicate efficiently with students and colleagues, building learning communities and creating a culture of professionalism in education institutions.

In Chapter 4, Tsakeni and Molotsi viewed IoT as a tool that also promotes students' creativity, accessibility and collaboration. They explored its usefulness in online teaching and learning and posited that as teachers integrate IoT, they should also ensure social presence in the online classroom. The 'social presence theory' was developed by Short, Williams and Christie (1976) to describe the ability to transmit social cues when using social media platforms. In the context of online teaching and learning, Picciano (2018:119) defined it as, 'a student's sense of being in and belonging in a course and the ability to interact with other students and an instructor'. With the focus on HE, Tsakeni and Molotsi argued that the two elements are essential for forming a critical platform through which the transformation of communication and social interaction in HE becomes possible. We embrace several benefits brought by IoT, but its barriers deprive students of social life in universities and lack of direct orientation. Thus, Tsakeni and Molotsi argue for social presence to fight this barrier. Although introducing an online social presence is deemed to overcome some barriers, the use of IoT is not a viable solution for the students who are involved with applied subjects (Al-Qozani & Aleryani 2018).

Teacher efficacy in the 4IR

Barni, Danioni and Benevene (2019:1645) argued that teacher efficacy is about 'teachers' beliefs in their own ability to handle the tasks, and challenges related to their professional day-to-day activities'. This plays a key role in influencing important academic outcomes. It is their personal values that drive their goals and behaviours (Barni et al. 2019). According to Ross and Bruce (2007, cited in Freeman 2008:14), the following behaviours are common in highly efficacious teachers:

> [*H*]igh goal selection, high exertion of effort, persistence, high student achievement, improved instructional practice, willing implementation of innovative teaching ideas, mutual classroom control with students, close monitor of lower ability students, improvement of students self-concept, motivation even triggered by failure, acceptance of personal responsibility for successes and failures, resourceful, self-reflective, victorious over external challenges. (p. 14)

Babane in Chapter 5 argued that the teacher's beliefs about their competence in curriculum delivery are very crucial. However, she further argued that in South Africa, diverse learner population threaten teacher efficacy. Navigating within the terrains of multiculturalism and multilingualism proves to be a threatening and frustrating process. Teachers are trained in the traditional ways of teaching and find it difficult to promote digital technology for meaningful teaching and learning. In Chapter 6, Kadenge argued that the role of teachers should be changed completely to be relevant in meeting the 4IR demands and empowering them to become positive change agents.

Babane further argued that we should rethink the teaching styles within the 4IR, and she proposed digital storytelling and teachers should embrace the use of multimedia for them to restore their efficacy.

Teacher technological literacy and readiness for 4IR uptake

Universities worldwide and particularly in South Africa are seen as not doing enough to equip their teachers for the 4IR; yet, companies and corporate leaders are already operating in a new era where robotics, automation and big data analytics are transforming the world into a completely new way of living and working (Penprase 2018). There is a general belief that multidisciplinary and interdisciplinary discourses in HE sector are urgently needed in understanding and solving global and local problems in a comprehensive manner. Holley (2017) argued that the challenges facing the 21st-century society are complex, and therefore, a multifaceted approach in dealing with such challenges is needed. Thus, interdisciplinary learning which involves interaction and integration of knowledge from different disciplines is treated as a matter of urgency. Many scholars researching interdisciplinary learning unanimously agree that the discourse is a complex task for universities (see, e.g. Holley 2017; Yamada 2018). However, there is critical need to respond to this quest as it helps to realise that 'knowledge is unbounded and potential discoveries lie outside compartmentalised structure' (Holley 2017:2). This theme seeks to understand how teachers in the South African HE system operate in a technologically driven education environment. Technology is seen as vital in promoting a better understanding of disciplines and further supports interdisciplinary learning. Thus, teachers need to be equipped with such skills. In Chapter 6, Kadenge noted the challenges associated with TPD and suggested that we need a parallel discussion that considers TPD and technological advances. Butler-Adam (2018) argued that 4IR is not solely about technology and digitalisation, but it also involves other skills relevant for the era and its new challenges. In tandem, Selamat et al. (2017) argued that teaching students to acquire technical skills alone without the mindset shift of cultivating, using and applying critical and creative thinking and problem-solving is not enough for the 4IR revolution.

Pedagogical readiness and preparedness in the 4IR

Aprianti and Sahid (2020) argued that in the 4IR era, the teacher needs four competencies to remain useful in imparting knowledge to their learners. The first competence is pedagogical which involves the teacher's ability in the teaching and learning process of learning management. Secondly, teachers also need social competence that involves the teachers' ability to communicate

and interact effectively with learners, parents, guardians and co-educators and thirdly, personality competence is also vital in reflecting 'a stable and mature, intelligent and authoritative personality, acting as an example to students and having a noble and solid character' (Aprianti & Sahid 2020:64). Lastly, the teacher needs to master professional competency, be an expert in their teaching method(s) and master and know the content of their learning and teaching support materials (LTSM).

These four competencies must be integrated with digital technology because the learning era of 4IR requires students to pay more attention on how things can be done easily and quickly using the 4IR technologies. Consequently, teachers must act more like facilitators, motivators, inspirers, mentors, and develop imagination, creativity, character, teamwork, and social empathy (Aprianti & Sahid 2020:65). In the case of South Africa, Luckay in Chapter 8 of this book argued that while there is a policy that promotes the incorporation of technology in the classroom, existing research shows that in-service teachers rarely incorporate technology into their teaching appropriately and pre-service teachers also struggle to incorporate technology in teaching. She further argued that teachers are not ready because they only possess very basic skills of technological literacy, and therefore, they are far from incorporating innovations using technologies. Looking specifically at science practical, Tsakeni in Chapter 9 argued that teachers need to obtain skills in computational thinking so that science practical would be possible using digital technologies. Similarly, Krishnannair and Krishnannair in Chapter 3 argued specifically for mathematics and postulated that there is a great need to establish a relationship between MP and SJM in the 4IR environment. Thus, Olivier in Chapter 4 argued for multimodality as a priority for teachers and learners to be adequately equipped with various modes of technology to choose from. South Africa, therefore, must transform its education focus and the delivery model to be responsive to the needs of the 4IR. In Chapter 1, Maringe and Chiramba argued that the:

> [*C*]urrent curriculum does not prepare learners with the relevant skills or education for the 4IR. They further argued that teachers lack training and development to teach a 4IR oriented education and the disparity between urban, rural and township schools exacerbate the situation. (See ch. 1)

The prospects for curricula transformation

The challenges of curriculum transformation are global (West 2014 in Mendy & Madiope 2020), and it seems this challenge has received less attention. Curriculum transformation in the 4IR means opportunities for education systems to advance their economic prospects through innovative technology. The literature, as indicated in the previous sections, reveals that teachers remain trapped in the traditional ways of delivering pedagogical content. It is

for this reason that curriculum innovation must include the incorporation of educational technology in order to enhance the learning experience; learners should be able to successfully use computers, tablets, mobile phones, social media, virtual environments, and various technological tools to learn in the 4IR era. Mutekwe in Chapter 10 argued that curriculum can be transformed using social media pedagogy, namely, WhatsApp, Twitter, Facebook, Instagram, LinkedIn or YouTube. Embracing these commonly used social media technologies can be a starting point in integrating technology and that would assist us with a gradual transition to using advanced technology that hugely assists with huge innovations. Naidoo and Sing-Pillay in Chapter 11 argued that we need advanced pedagogy to succeed within the 4IR. To ensure curriculum transformation, they advocated for four pedagogies, namely, blended learning, technology-based pedagogy and collaborative pedagogy. However, the question remains: Are teacher training institutions preparing students with such kind of progressive pedagogy to flourish within the 4IR? Naidoo and Sing-Pillay argued further that teaching in this era is multifaceted and requires various types of interconnected knowledge. In other words, curriculum transformation in the 4IR requires knowledge of pedagogy, technology and content. Although all kinds of knowledge are crucial, special emphasis is placed on understanding which technology-based tools are appropriate for teaching various concepts. Naidoo and Sing-Pillay discussed the TPACK framework as useful in understanding and implementing a transformed curriculum.

Given the above-emerging themes and the arguments developed within them, as we bring this book to a close, we summarise some of the challenges and opportunities that the 4IR bring to the field of teacher education in the South African context.

Challenges of the 4IR: A critique

Across the pages of this book, there is a discernible cautious optimism about the prospects and challenges that teacher education will be faced with in the era of the 4IR. Three fundamental challenges stand out prominently. They are as follows: it is humans, not technologies that drive change; the persistent and deepening crisis of the digital divide and a growing global digital coloniality.

Humans, not technologies drive change

The fact that each of the preceding industrial revolutions has been linked to some technological development/s appears to have strengthened the belief that it is the technologies that drive change. The 1IR for example, grew out of the mechanisation of labour, through the use of water, steam power and railway systems in the late 18th to the early 19th centuries. The 2IR, enabled by the discovery of electricity, led to mass production in complex assembly lines for an

ever-growing consumption-oriented population. The 3IR was based largely on the development of computers and automation. This 4IR is also called the 'cyber-physical revolution' due to the increasing interconnectivity of the physical, biological, and digital worlds (Schwab & Sala-i-Martin, 2016). (Schwab & Sala-i-Martín 2016). However, these technologies do not have a life of their own. Humans design and develop technology with specific intentions and purposes, even though they can be applied in different and broad fields, which may not have been intended initially (Bull & Maron 2016). The fact that humans drive change implies the agentic power of people over the machines and technologies, which essentially can only do what they are programmed for. Fame and wealth tend to follow the people who design these technologies making it increasingly difficult to decouple the financial motive as a driver of technological advancement. To that extent, technological advances tend to be closely linked to the capitalist rationale of wealth creation and very rarely to equalising opportunities, especially amongst disadvantaged communities. 4IR cannot be looked upon as an inevitable revolution that we must all embrace without question, but rather as an opportunity, especially in the developing world, to explore how its potential can be used to improve the lives of marginalised people (Zervoudi 2020). Where technologies are a threat to the lives and livelihoods of people, especially the marginalised, we have a responsibility to discard, modify and transform them in service to the more important goals of equality and equal opportunities, especially for the most disadvantaged.

The persistent and deepening digital divide

The rich become richer while the poor almost always become poorer in a world designed and controlled by those with wealth. Technologies are not cheap, and people with little or no disposable incomes are less likely to purchase these for use in the era of technologisation and digitalisation. The increasing tendency to measure development on levels of urbanisation creates stark contrasts between cities and the rural areas where most people in the less developed countries live (Kamete, Tostensen & Tvedten 2001). In South Africa, despite rapid urbanisation, census data show that almost 60% of the population continue to live in rural areas of the country (Statistics South Africa 2011). Because of low investment in these areas, both by government and the donor and Non-Governmental Organisations communities in preference to urban areas, rural populations have lower access to and utilisation of technologies. The current COVID-19 pandemic has cruelly exposed the inequalities that exist in South Africa. Afflicted by low incomes, and various other poverty-induced factors, rural communities and their schools are a pale shadow of their more affluent urban counterparts. The inequalities in access and utilisation have substantial impact on students' curricula experience and teacher efficacy regarding implementation of technology in their schools (Torres & Giddie 2020). The opportunities presented by the 4IR thus have differential impacts on learners in different parts of the country.

A growing global digital/technology coloniality

'Digital colonialism, the use of digital technology for political, economic and social control' is an ever-increasing threat to the independence and self-determination of people in the less developed world, especially those from the colonial experience (Kwet 2019:422). The proliferation and widespread adoption of western digital technologies and operating systems/platforms such as Microsoft Windows, Google and Android, amongst others in most parts of the world, impose models and structures for thinking, communicating and learning, which entrench western knowledge hegemonies over large swaths of unsuspecting people around the world. In addition, because of weak data protection laws in many developing nations, the western owners of the technologies have capacity to access other nations' data sets for marketing, surveillance, business and other purposes. As Kwet (2019) explained:

> [*U*]nder digital colonialism, foreign powers led by the US, are planting infrastructure in the global south engineered for its own needs, enabling economic and cultural domination while imposing privatised forms of governance. (p. 423)

As AI capabilities increase, western owners of technologies and digital platforms also have increased access to multiple data sources to analyse in ways that enhance their business potential (Martens et al. 2018). Whereas the original colonialism was based on brutal military force, modern day colonialism focusses on controlling knowledge resources that are at the heart of contemporary knowledge economies.

The opportunities of the 4IR

There is no doubt that the 4IR brings numerous opportunities for transforming HE and teacher education. As these have been extensively explored in the chapters of this book, only brief reference will be made in this chapter.

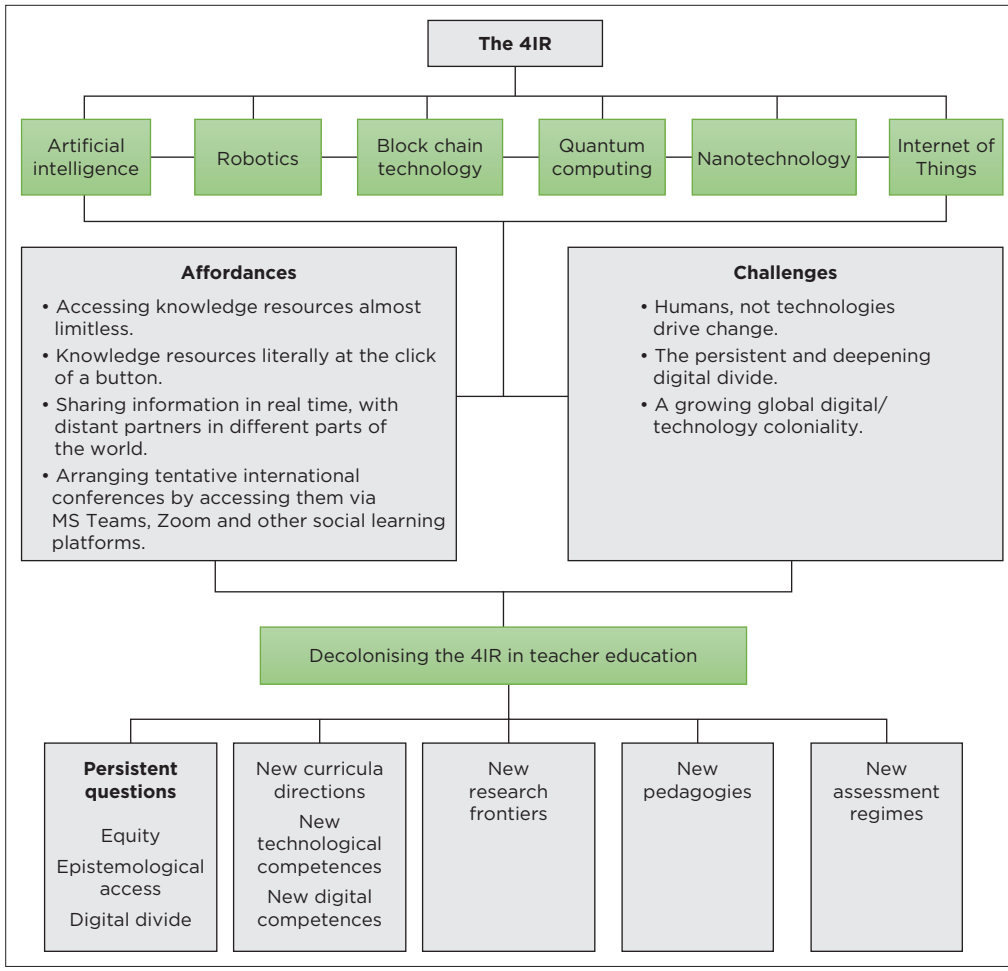
The most obvious is improved access to data and knowledge repositories (Martens et al. 2018). If a smart device such as a smartphone, laptop or tablet has access to the Internet and Wi-Fi, the possibilities of accessing knowledge resources are almost limitless. Whereas in the past, students depended on libraries as knowledge resources, and on inter-library loan systems to access resources in distant places, the increased interconnectedness of technological and digital systems enables students to have access to a wide range of knowledge resources literally at the click of a button.

Another important opportunity is the potential for sharing information in real time, with distant partners in different parts of the world (Kraut, Egido & Galegher 2014). Through MS Teams, Zoom and other social learning platforms, it is possible to arrange international conferences and meeting rather than having F2F modalities for knowledge and information sharing. In the context of the current pandemic, these possibilities are shaping new ways of delivering

teaching and learning and of sharing and creating knowledge with others who may be thousands of miles away from our campuses.

A whole range of other opportunities exist in the potential of the 4IR to drive curriculum change, new pedagogical approaches, innovation and new assessment practices, which have been explored effectively in the chapters of this book (MacDonald 2008).

Clearly, the 4IR is a double-edged sword that can cut deep in two directions. We end this book with a proposal for its cautious use and adoption in teacher education. Figure 11.1 below shows the characteristics of the 4IR, its affordances and challenges and opportunities for decolonising the 4IR in teacher education.



Key: 4IR, Fourth Industrial Revolution.

FIGURE 11.1: Characteristics of the 4IR, its affordances and challenges and opportunities for decolonising the 4IR in teacher education.

Conclusion

Towards a knowledge ecosystem for teacher education

The decolonial turn (Grosfoguel 2007) offers, arguably, the best proposition for mitigating the three critical challenges associated with the 4IR. In the previous section, we argued that humans, not technology which the 4IR places on a pedestal, are the real agents of change that left unchecked, the digital divide is likely to widen and deepen, especially in the less developed world, resulting in persistent inequalities in epistemological access between the affluent and less affluent segments of society and finally, that a combination of all this will lead to an intensified technological coloniality (Maldonado-Torres 2011) characterised by persistent dependence of the technologically less developed world on the more technologically developed world, skewed technology transfer arrangements that will result in epistemic recolonisation and the concentration of wealth in the more technologically developed world. No other ideological framework stands in stark opposition to these trends than the decolonial turn. In this final part, we argue for the need to work with both ideologies through a knowledge ecosystem framework (Järvi, Almpanopoulou & Ritala 2018).

Drawing on its biological origins, the notion of ecosystems defines a group of living and non-living entities which reinforce species continuity. The members of an efficient ecosystem provide mutual support to each other, some as producers and other as consumers, while other elements may provide natural recycling of materials to ensure the continuity, reproductive efficiency and sufficiency of the entire group.

We argue that both the 4IR and decolonisation are based on clearly identifiable knowledge economies (Valkokari 2015), which by design and by dint of accident or opportunity can lead to diametrically different destinations. The 4IR creates opportunities for accelerated knowledge expansion in service to acknowledged global challenges such as climate change, arms proliferation and the eradication of poverty, amongst others. Most of this is, however, done with the idea of maintaining western dominance of other world systems (Maldonado-Torres 2011). On the contrary, in post-colonial nations, development is prioritised around the ideas of equality of access, restoration of human dignity, poverty eradication and redistributive justice. We argue that the separate knowledge economies of the two need to be reconstituted as a framework for development in teacher education through the creation of knowledge ecosystems.

Valkokari (2015) argued that the concept of knowledge ecosystem is often used without a clear definition of what it is and what it entails. In trying to show what it entails, the International Alliance of Research Universities (IARU)

contends that research intensive universities are divided into three main value streams, namely, *research* defined as the production and sharing of new knowledge through publications; *education* defined as candidates' knowledge and soft skills, and lastly, technology transfer which consists of collaboration with the outside world. Por (1997) in Chang and Tan (2013:25) articulated that:

> [*K*]nowledge exists in ecosystems, in which information, ideas and inspiration cross-fertilise and feed one another, implying that the interactions that occur among individuals, organisations and knowledge artefacts are the primary sources of learning, knowledge creation, sharing and utilisation. (p. 25)

Mutual co-existence, sharing of information, trans-inspirational opportunities and conjoint working will become the raison deter of the knowledge systems we are proposing.

A group of Wiley publication editors came up with 10 elements of effective knowledge ecosystems as listed below (Lucidea 2019:n.p.):

- allows for flexibility
- embeds learning in everything
- sets clear open innovation objectives
- overcomes selfishness by using selfishness
- actively identifies critical knowledge
- fosters authentic leadership
- balances your open and closed activities
- creates a competitive, free market-like environment
- reviews the quality of the knowledge
- creates a psychologically safe environment.

They argued that for knowledge ecosystems to be functional knowledge management needs to fit tightly with the organisation's culture, workflows and strategic priorities.

Teacher education, whose core business is to prepare teachers for the school systems (Tirri 2018), does its work in four critical areas of research, curriculum development, teaching and learning and practice teaching in schools. The creation of knowledge ecosystems to embrace the knowledges, values and behaviours that these two ideologies can offer will require that at every level, five fundamental questions be asked which will draw on synergies from both these knowledge economies. These questions are as follows:

1. What contemporary and indigenous knowledge systems need to be brought together to yield the greatest value for the students?
2. How do we plan for the knowledge systems to speak to each other in the work of training teachers?
3. How do we ensure that all our students access these knowledges and derive the maximum benefit from their utilisation?

4. How do we develop appropriate evaluation mechanisms to measure learning and to promote continuous learning and reflection across the areas of teacher preparation?
5. What do we need to do to ensure the preservation of human dignity and equality in both independent and collaborative work we do with teachers in their different settings?

In the final analysis, it is humans not machines who change the world around us. This calls for an education that has contemporaneity and is rooted in historical and cultural embeddedness, developed deliberately around frameworks that allow continuous negotiation and reflection and always engaging those aspects that carry the potential for leaving many of our learners in the dark spaces of runaway developmental models that selectively cater for some groups and not all our children.

The 4IR presents both opportunities and threats to the systems we deploy to pursue issues progress and development. In South Africa, teacher education is conducted in a socio-economic environment that offers differentiated access to the goods of society. The presence of substantial technological and digital divides in societies, especially those in poor nations, requires additional interventions to level up societies to experience similar levels of benefits from the 4IR. Left to its own devices, the 4IR can be a runaway discourse that might create more inequalities in societies that are already under the excruciating pain of unequalness.

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Chapter 1

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Index

This book is a one-stop shop for 4IR in teacher education in South Africa. The authors put together knowledge systems about technologies in the 4IR as they are applied to teacher education in the context of South Africa. Any reader of this book will gain knowledge of challenges, constraints, possibilities, theories, methodologies and software in 4IR. The chapters provided views on the technological advances from the First, Second and Third Industrial Revolutions, from previous ages to the present. The writers provide definitions, methodologies, theoretical frameworks and examples from disciplines. Furthermore, the history of teacher education in South Africa, culture, contemporary debates, development models, human dignity and equality matters were discussed. Moreover, there is a wealth of knowledge that includes different new ways of sharing knowledge, for example via Teams, Zoom and other social learning platforms. A new thinking about how to move forward with Teacher Education in the 4IR aspects of artificial intelligence, robotics, blockchain technology, quantum computing, nanotechnology, and Internet of Things is outlined.

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This manuscript presents a vibrant and varied selection of topics related to 4IR and teacher education. The chapters present an interesting variation of understandings and opinions about teaching with technology as we have it now, and teaching in the 4IR environment. The book can potentially make a contribution to our understanding of how teacher educators and their students can prepare for the 4IR. The book presents theoretical and conceptual understandings of 4IR, and there are some useful lenses that will be valuable for researchers in the field of 4IR and teacher education in the South African context.

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