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Innovations in online teaching and learning

Case studies of teacher educators from South Africa during the COVID-19 era

EDITED BY
Judah P. Makonye & Nokulunga S. Ndlovu

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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 highly infectious and deadly coronavirus disease 2019 (COVID-19) pandemic has accelerated the adoption of computer-assisted instruction (CAI) and computer-based instruction (CBI). This book's research is on online pedagogical approaches devised by teacher educators and researchers to circumvent face-to-face (f2f) curriculum delivery, which increases the disease infection rate. This book reports on case studies by teacher educators and researchers on teaching their student-teachers with technology in a way that advanced not only communication but also the cognitive growth of students in relation to disciplinary knowledge.

The value of this book is that it reports on pedagogical innovations in using digital technologies in teacher education. These are to be shared by other scholars and specialists in pedagogy. The challenge is that presently, many educators are uncertain about how to productively use digital technologies in teaching, learning and assessment. This is the plight – the gap that this book aims to bridge. Before COVID-19, f2f instruction was predominantly used as the main mode of teaching and learning, which suddenly became untenable. Educators had to learn how to use electronic platforms, video conferencing rooms, apps and social media for teaching purposes. This is the subject of this book's research.

The effective use of technology in teaching and learning is a problem that many educators face every day. They are confronted with the problem of how they can optimise teaching and learning with digital technology if they are to continue to be relevant and sustain the education project. This book engages that problem with respect to teacher education. It shares sub-Saharan scholars' experiences in designing and implementing information and communication technology-based instruction at a time when it was not possible to have normal lectures as a result of the COVID-19 pandemic lockdowns. Sharing this research with other scholars is imperative to move the theory and practice of CAI and CBI forward for the benefit of learning. The authors of the chapters in this book have conducted research at 11 universities in South Africa and Nigeria. This ensures that this book draws from the wide-ranging experiences of scholars from different backgrounds. The rich discussions that emerged from this research enable academics to learn from others' innovative moments that occurred as a result of the COVID-19 pandemic pressure. Researchers have an opportunity to learn from this book how to deal with the tantalising teaching and learning problem of our time: how can the use of digital technology transform teaching and learning in general and teacher education in particular?

The scholarly contributions in this book are varied. They cover theoretical nuances for information and communication technology use in education, considerations for the use of computers in the classroom, pedagogical thinking and pedagogical integration of ICTs in education, affordances of iPads in visible teaching and learning, supporting student cognition in languages, Mathematics, Science and Engineering, Graphics and Design with ICTs. The use of software applications such as GeoGebra and Microsoft Excel in teaching and learning Mathematics is researched, among others.

The scholars in this book used both conceptual and empirical methodologies, mostly in qualitative set-ups. I declare that no work in this book is plagiarised. I also declare that the production of knowledge in this book is original and that the book represents scholarly discourse on the use of digital technology in teacher education. The recommendations in this book can be used in blended learning beyond the COVID-19 era, as curriculum delivery methods are bound to change.

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List of abbreviations and acronyms

4IR	Fourth Industrial Revolution
AACE	Association for the Advancement of Computing in Education
AD	academic development
AFHEA	Associate fellow of the Higher Education Academy
AI	artificial intelligence
AREA	Africa Reggio Emilia Alliance
ASCILITE	Australian Society for Computers in Learning in Tertiary Education
BICS	basic interpersonal communicative skills
CAI	computer-assisted instruction
CALP	cognitive academic language proficiency
CANRAD	Centre for the Advancement of Non-Racialism and Democracy
CAPS	*Curriculum and Assessment Policy Statement*
CBI	computer-based instruction
CDP	critical digital pedagogic
CECD	Centre for Early Childhood Development
CFT	Competency Framework for Teachers
CIECT	Centre for Innovative Education and Communication Technologies
CK	content knowledge
CLTD	Centre for Learning, Teaching and Development
CoI	community of inquiry
CoP	communities of practice
CP	critical pedagogy
CPD	continuous professional development
CPL	continuous professional learning
CR	critical realism
CT	critical thinking
CUP	Common Underlying Proficiency
DBE	Department of Basic Education

DF	degrees of freedom
DGCS	dynamic geometry computer software
DGS	dynamic geometry software
DoHET	Department of Higher Education and Training
DOK	depth of knowledge
EDIET	Educational Information Engineering Technology
EGD	Engineering Graphics and Design
ERT	emergency remote teaching
ERTL	emergency remote teaching and learning
EU	European Union
f2f	face-to-face
FAL	first additional language
FET	Further Education and Training
FP	Foundation Phase
FTP	file transfer protocol
GMAT	Geometry Mathematics Achievement Test
GUI	graphical user interfaces
HE	higher education
HEI	higher education institution
HEIs	higher education institutions
HELTASA	Higher Education Learning and Teaching Association of Southern Africa
HOD	head of the department
HoS	head-of-school
IADIS	International Association for Development of the Information Society
ICT	information and communication technology
ICT-CFT	*Information and Communication Technology Curriculum Framework for Teachers*
IKS	indigenous knowledge systems
IQ	intelligence quotient
IT	information technology
ITE	initial teacher education
L&T	learning and teaching
LMS	learning management systems
LoLT	language of learning and teaching
LTSM	learning and teaching support material
MBA	Master of Business Administration
MGSLG	Matthew Goniwe School of Leadership and Governance

MR	mental rotation
NCE	Nigeria Certificate in Education
NQF	National Qualification Framework
NRF	National Research Foundation
OER	open education resources
PCK	pedagogical content knowledge
PD	professional development
PEOU	perceived ease of use
PGCE	postgraduate certificate in Education
PGCHE	postgraduate certificate in Higher Education
PK	pedagogical knowledge
PLC	professional learning communities
PLN	personal learning network
PU	perceived usefulness
RADLA	Research and Doctoral Leadership Academy
REAL	Researching Education and Labour
SACE	South African Council of Educators
SAL	second additional language
SAMR	substitution, augmentation, modification and redefinition
SARAECE	South African Research Association for Early Childhood Education
SOTL	Scholarship of Teaching and Learning
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
SUP	separate underlying proficiency
TAM	technology acceptance model
TCK	technological content knowledge
TK	technological knowledge
TPACK	technological pedagogical and content knowledge
TPD	teacher professional development
TPK	technological pedagogical knowledge
TUT	Tshwane University of Technology
TVET	technical and vocational education and training
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTAUT	unified theory of adoption and use of technology
UWC	University of the Western Cape

VR	virtual reality
WSoE	Wits School of Education

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Acknowledgements

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Part 1

Issues of ICT integration in teacher education

Chapter 1

Computers in the classroom: What informs what we teach the teachers?

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Abstract[1]

This chapter explores what student-teachers need to know about learning in e-learning. It adopts a history-of-ideas approach in examining the five most influential psychological theories of learning – behaviourism, cognitivism, constructivism, socioculturalism and embodied cognition theory – that have implications for educational technology. The chapter suggests that five big ideas, one from each of these theories, might be synthesised to assist teachers in using computer technology in their classrooms. It argues that this is the most productive way to prepare students in a teacher education programme for the pedagogic integration of information and communication technologies (ICTs).

1. This chapter is a revised version of Moll (2012). It has been updated, developed and expanded here with the kind permission of Macmillan South Africa.

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Introduction

In any pedagogical terrain, teacher educators are faced with a bewildering array of 'theories of learning'. These usually have particular implications for teaching, and when e-learning is added into the mix, we often fall back on 'choosing' whichever learning 'paradigm' makes the most sense to us, and we advise the emerging teachers whom we are teaching to do likewise. In this chapter, I recognise that there are different perspectives in e-learning theory, the most influential of which are set out in Figure 1.1.

However, I take a rather different view to that of 'paradigm' theory. This chapter suggests that this sequence of learning theories presents a roughly accurate, *accumulating* history of ideas rather than a series of mutually exclusive approaches. Subsequent theories both refute certain aspects of previous theories and incorporate important insights from them in the ongoing refinement of our knowledge of learning and teaching. In particular, I suggest that important insights taken forward from theory to theory are crucial in understanding the pedagogic integration of ICTs in the classroom.

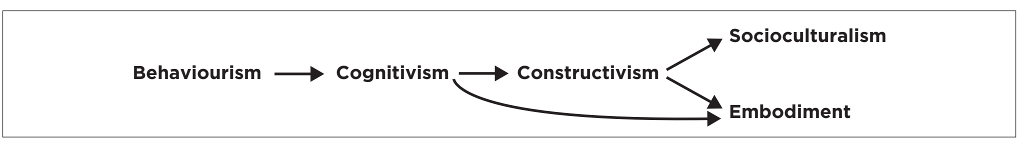
It is widely recognised that, in the current coronavirus disease 2019 (COVID-19) context, the rapid transition to emergency remote teaching (ERT) tends merely to digitise rather than transform courses (Crawford 2021; Le Grange 2020). The often repeated claim that the COVID-19 pandemic has accelerated and demonstrated the possibilities and reach of polysynchronous online learning does not allay concern about its creeping technicism. As Sean-Michael Morris (2020) points out, 'the pandemic has not been learning design's finest hour' – the mass movement into online teaching spaces by teacher educators with little history in digital learning amplifies its technicism and stifles its critical pedagogical possibilities. We need to look to theories of learning and pedagogy to understand what we are doing more than ever before.

In Figure 1.2, a history of learning theories and their implications for the pedagogic integration of ICTs is presented in this historical narrative.

Behaviourism	**Cognitivism**	**Constructivism**	**Socioculturalism**	**Embodiment**

Source: Author's own work.

FIGURE 1.1: Different perspectives in e-learning.



Source: Author's own work.

FIGURE 1.2: A history of learning theories.

My argument is that this understanding of the progressive history of ideas in the psychology of learning presents the teacher educator with a much more educative way of developing the teaching skills of their students, not least in the integration of ICTs into their lessons. I suggest that this approach provides a sequence or learning pathway along which to introduce education students to the pedagogic integration of ICTs. This strategy is particularly generative, whether it be in a focused, in-depth course on e-learning itself or in a school subject–related course, like ICT integration into the pedagogy of Biology, History or Mathematics.

Therefore, I approach the different theories of learning as an account of the following historical development of ideas:

- By the middle of the last century, behaviourism was the dominant idea about learning. It had 'won' the nature–nurture debate in psychology by its emphasis on external reinforcement as the cause of new, learned behaviours.
- It was soon challenged by cognitivism, which brought the human brain and mind back into the picture. These theories place emphasis on thinking, as well as neurological possibilities and constraints in learning.
- Then along came constructivism, which accused both behaviourism and cognitivism of too passive a view of learning. Constructivists emphasise the active construction of knowledge by learners, via both biological and social mechanisms.
- More recently, sociocultural learning theory (including connectivism, a variant focused on e-learning) went beyond constructivism. It argues that learning should be considered a social rather than an individual process.
- Embodied cognition theory, also recently, went beyond constructivism but in a different way. It construes human learning as a bodily relationship with the world, as the actions of 'feeling beings who think'.

Each theory engaged in this chapter is, or was, progressive for its time in its implications for educational practice. Although we cannot 'read' a prescription for teaching from a theory of learning, each suggests a move away from what we think of as traditional teaching: 'chalk-and-talk' methodology. This refers to the teacher who mostly stands in front of the class lecturing, expecting that learners will learn simply by being told something. Alternatively, they write things up on the board or display them on Microsoft PowerPoint slides, believing that by copying and replicating them, learners will come to new understandings. However, we now know that we do not learn by being *told* something. Nor do we acquire knowledge by memorising something by rote.

Behaviourism

In the psychology of learning, the first half of the 20th century was about the search for a *science* of human behaviour. Psychologists looked to the natural sciences for a model of how they could predict and control the behaviour of human beings. Laboratory experiments were considered to be the place to establish laws of behaviour. Learning theory was driven by the idea that if we could predict and control the behaviour of children in the classroom, we would be able to improve school performance.

Behaviourism was the dominant theory of learning at this time. It is built on the idea that *all* the behaviours that we produce are caused by environmental stimuli. The learning performances of a child in a classroom, for example, are controlled by the stimulus conditions of the learning environment that we set up there. This idea of a scientific law of learning can be represented as seen in Figure 1.3.

S is the stimulus and R is the resultant behaviour or response. Note here is that there is no interest in the mind, thoughts, feelings or anything that might be considered to be inside the learner. This is deliberate. Behaviourists think that it is not really possible to observe or measure these things. Therefore, they cannot be part of the science of behaviour. Some behaviourists even refer to thoughts and feelings as 'ghosts in a machine' – we might believe in them, but they do not really exist! From a strict behaviourist perspective, a theory of learning needs not consider internal states of mind. Rather, it needs to be functional – it must help us to take control of learning and produce optimum performances in our learners. As the most famous behaviourist, B.F. Skinner (1974), puts it:

> [*T*]he most important objection to inner states is not so much that they do not exist, but that they are not relevant in a functional analysis of behaviour. [...] Many supposed inner causes of behavior, such as attitudes, opinions, traits of character, and philosophies, remain almost entirely inferential [...] no evidence of the inner causes is available except the behavior attributed to them. (p. 159)

This is why commentators refer to behaviourism as a 'black box' theory (Hamlyn 1990). For behaviourism, the mind is like a black box (Figure 1.4). We do not need to bother ourselves with it to produce an effective theory of learning for the classroom.

Skinner gives us two important concepts to take forward in understanding learning with ICTs: *reinforcement* and the *shaping of behaviour*. He finds, in his laboratory work with rats and pigeons, that the most important stimulus for

$$\mathbf{S} \longrightarrow \mathbf{R}$$

Source: Author's own work.

FIGURE 1.3: The form of a scientific law of learning in behaviourism.

$$\mathbf{S} \longrightarrow \blacksquare \longrightarrow \mathbf{R}$$

Source: Author's own work.

FIGURE 1.4: Behaviourism styled as a 'black box' theory.

learning is not the one that comes before the response (the 'eliciting' stimulus) but the one that follows the response (the 'reinforcing' stimulus). When a response is followed by a reward, then it will increase in both strength and frequency. Likewise, if a response is followed by an unpleasant stimulus, then it will decrease in frequency. We all know this latter strategy well – punishment – because it was such a strong part of our homes and schools.

Skinner recognises that punishment can work to control behaviour. But he reaches the obvious conclusion: it cannot do much to help us build up new responses in the behaviour of the learner. He insists that *positive reinforcement* is the most effective way to produce desired performances on the part of learners in the classroom. As teachers, our main job is to set up learning environments in which we manage reinforcement effectively. We integrate ICTs pedagogically with this purpose in mind.

The classroom learning that we want to produce using positive reinforcement is complex. Normally, it is not possible to produce desired performance with a once-off reinforcement. Rather, we need to identify an existing behaviour that approximates the 'target' behaviour. Then, we employ reinforcement gradually to change it in small steps towards that outcome. For example, if we want to train a pigeon to rotate three times in a clockwise direction, we might manage positive reinforcement in the following way:

1. reinforce a simple turn to the right
2. reinforce a series of much more pronounced turns to the right
3. reinforce a 180° turn to the right
4. reinforce a full 360° turn
5. reinforce two full 360° turns
6. reinforce three full 360° turns.

And there you have it. This repeated reinforcement of small steps towards a more complex behaviour is called 'shaping'. In the procedure mentioned, we put in place a strong tendency in the pigeon to turn around and around. It will continue to do so as long as it is reinforced for this behaviour.

Shaping has hugely influenced educational design and computer-based education. In any classroom, we can see this idea at work. Teachers often define a series of responses towards a final outcome and then reward these progressively in a lesson or unit of work. There are two important principles here: (1) at the beginning of a lesson, we must assess established behaviours to determine where instruction should start and what the first step should be; and (2) we then define a series of behavioural steps towards the final outcome, each of which represents a more complex level of performance. We emphasise mastery of this sequence of responses in the instructional process.

Thus, from behaviourism, we arrive at the idea of *programmed instruction*, also known as mastery learning (Twyman 2020). Historically, this is probably the most prominent single theory on e-learning. Behaviourism is, in these terms, still massively influential in education today (Molenda 2018; Root & Rehfeldt 2021). Its advocates tend to sidestep the question of 'inner states' and concentrate on the proven ability of behaviour modification techniques to influence learning and bring about desired educational objectives (Kitchener 1974).

The need for programmed instruction leads Skinner (1968) to advocate the use of a *teaching machine*:

> [*T*]he device makes it possible to present carefully designed material in which one problem can depend upon the answer to the preceding problem and where, therefore, the most efficient progress to an eventually complex repertoire can be made. (p. 24)

From a behaviourist perspective, the teacher has a particular role to play in a classroom as a manager of reinforcement procedures. But they cannot do this on their own (Skinner 1968):

> These requirements [*of programmed instruction*] are not excessive, but they are probably incompatible with the current realities of the classroom. [...] An organism is affected by subtle details of contingencies which are beyond the capacity of the human organism to arrange. *Mechanical and electrical devices must be used*. [...] The simple fact is that, as a mere reinforcing mechanism, the teacher is out of date. (pp. 21–22; [*author's added emphasis*])

So the general behaviourist claim is that, without a teaching machine (in today's terms, a computer in the classroom), a teacher is incapable of delivering education effectively (Keenan, Presti & Dillenburger 2020; Watters 2011). In the terrain of e-learning, one indicator of this strong contemporary influence is the emergence of 'machine behaviourism' in online course design, 'in which "correct" forms of performance and conduct have already been decided, and learners are increasingly "nudged towards predefined modes of participation and behaviour" by programmed instruction' (Knox, Williamson & Bayne 2019:41–42).

One final point to highlight about behaviourism is the strong view of learner-centred education that it brought to the fore.[2] Skinner's view was that only a machine could manage classroom reinforcement in such a way that each particular learner could proceed through learning materials at their own pace, governed by their own interests. Inevitably, if the teacher does not employ programmed learning materials carried on a computer platform, the needs of each learner will be subjugated to those of the whole group. The teacher will lose sight of the needs of the individual learner, which is what happens in traditional classrooms. The integration of ICTs into our pedagogy helps us to strengthen the principle of learner-centred programme delivery.

2. It often claimed, not least in South African rhetoric about new curricula, that behaviourism is antagonistic to learner-centred education. Nothing could be further from the truth. Historically, behaviourists were among the first theorists to argue for individually-paced learning. Reading Skinner's writings on education, one is struck by his consistent search for systems of classroom delivery and management that will ensure that the needs of the individual learner are given primacy, rather than being subjugated to those of the group as a whole.

Cognitivism

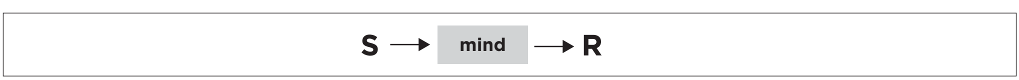
By the 1960s, psychologists had become disillusioned with behaviourism. Learning theory shifted from behavioural to cognitive models of learning. The 'cognitive revolution' of this period may be seen as one in which *information processing* in the mind replaced the notion that the mind is a 'black box' (see Figure 1.5). Psychologists became interested in cognitive processes such as thinking, problem-solving, language, concept formation, attention and memory. Cognitivism conceives learning as thinking. The implications of this shift for education are profound. Teaching and learning no longer concern themselves only with observable learner performance brought about by us manipulating stimuli. Now, it emphasises mental processing (Ertmer & Newby 2013:57). In classrooms, cognitive scientists focus on how information is received, organised, stored and retrieved by the mind in the learning process.

Cognitivism as a learning theory seeks to go inside the 'black box' (Hamlyn 1990). While stimuli and responses play a part in learning, the really important thing is the way our minds make connections between them (Figure 1.5). If we do not understand the way the mind works, then we cannot understand learning.

A watershed in the demise of behaviourism was Noam Chomsky's (1959) critical review of Skinner's *Verbal Behavior*. He pointed out that the only way we can know for sure what links a specific S and a specific R in any S–R connection is to know exactly what is in the mind of the learner. How else, he asks, can Skinner know which S to look at for which R? In order for an S–R connection to be established, it requires a strong idea of a mind that actively links stimuli and responses to each other.

Chomsky is an *innatist*. He thinks that the essential, generative processes of learning, such as attention, memory and language, are to be found in innate structures of the brain. We are born with them. To use the recent terminology of cognitive science, such learning processes are *hard-wired*. In education, we need to take into account the hard-wired processes of learning that make it possible to do certain things in the classroom and not others.

To understand classroom learning, we need to understand attention and memory. Cognitive science models how information is relayed from our sense receptors to the brain and how it is processed and stored in the brain. Memorisation has the following three facets (Atkinson & Shiffrin 1968), as portrayed in Figure 1.6:

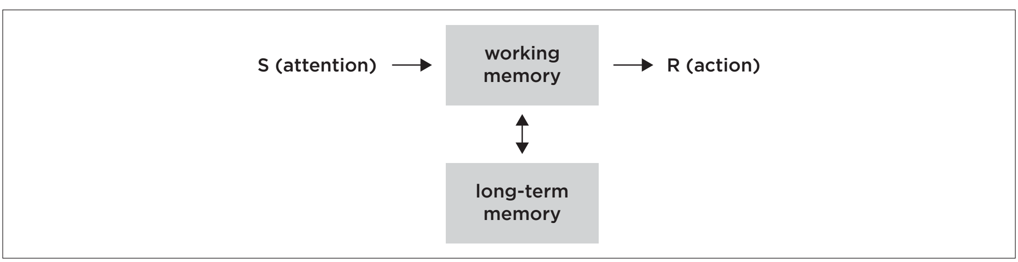


Source: Author's own work.

FIGURE 1.5: Cognitivism goes inside the 'black box'.

- **Sensory memory:** This is 'sensory attention', in which we are alerted to and notice incoming information. Sensory memory is large in scope: there are many things that our senses are aware of at any moment in time. But it is fleeting, its moments less than half a second in duration, and only some are drawn into working memory.
- **Long-term memory:** This is the storage capability that our brains have. Brain processes encode or organise and exercise control over information. Once we have processed information, it is stored in our brains and can last a lifetime. Long-term memory is huge, seemingly limitless, and organised in complex networks of information. Because our memories are encoded into long-term storage in this way, we can draw them into working memory (recall them) as we need to when we think and learn.
- **Working memory:** This is the thoughts, or units of information, that we can consciously hold in mind at any point in time. Working memory is neurologically limited in its capacity (Miller 1956) – it can hold 'seven plus-or-minus two' units of information in mind at any given moment.[3] It is time-limited, typically lasting for only 20 to 30 seconds. Despite these limits, working memory is where school learning happens. Working memory selectively draws in encoded information from sensory memory and recruits encoded information from long-term memory in order to make thinking possible. Thinking and learning is thus understood to be the conscious processing of information drawn simultaneously from both prior knowledge (long-term memory) and experience (sensory memory).

The process through which information is received and memorised is hard-wired. The brain links new information to already stored information in increasingly complex ways. It 'chunks' it together and stores it (Abadzi 2006:161–162). There is a vast amount of research suggesting that classroom teaching should be based on this bottom-line information processing model (Clark & Mayer 2007). In the wake of the rise of the brain sciences in the



Source: Author's own work.
FIGURE 1.6: The memory processes in learning.

3. Related research has sometimes indicated that working memory might hold five to nine units of information, or only two to four, when it comes to the 'chunking' of complex knowledge, at any one time. However, the key point remains the same: working memory is very limited in scope and in time.

1990s – 'the decade of the brain' – cognitivism is now prominent in education. Its key concepts, working memory and cognitive load, remain the contemporary focus of this theory (Buchner, Buntins & Kerres 2022; Van Merriënboer & Kirschner 2018).

Perhaps the most fundamental implication for teaching drawn from cognitivism is the theory of the *cognitive overload* of working memory. There are three types of cognitive load (Sweller 2010, 2020):

- **Intrinsic cognitive load:** The amount of information presented to a learner and the connections between different elements within it. If this is too complex, then cognitive overload occurs. A teacher avoids such overload by presenting information gradually and in small steps.
- **Extraneous cognitive load:** Irrelevant, distracting information not focused on the central ideas of the learning session. Teachers overcome this by focusing on essential, meaningful information only. Extraneous cognitive load also occurs when too many communication channels are employed to convey information at any one moment – this has crucial implications for e-learning.
- **Germane cognitive load:** This refers to essential information related to the learning task. This is what you want to emphasise as a teacher in such a way that it builds complexity and depth. Ideas and skills are always embedded in a complex web of other ideas and skills. Information that has been stored in long-term memory in a connected, meaningful and organised way is often much easier to retrieve. The central principle for lesson planning is 'the next concept to be learned in class [...] must fit at least one of the categories in students' minds and be connected to a high-level concept in the network. But the fit must be very precise and appropriate to the context' (Abadzi 2006:170).

Other things that teachers can do to maximise germane cognitive load are (Ertmer & Newby 2013):

1. use cues and examples to help learners connect new information with previously learned material
2. use 'worked examples' to achieve deliberate focus on learning tasks from moment to moment
3. teach learners *advanced organisers* – thinking techniques to organise new information – analogies, hierarchical relationships, matrices, et cetera (Ausubel 1960)
4. teach cognitive strategies such as outlining, summarising and synthesising to help learners structure and sequence information

Cognitivists naturally go to computers to think about learning. In cognitive science, there is a close relationship between thinking about cognition and thinking about computers. In the Second World War (WWII), machines were invented that could crack codes – these were the first computers. They seemed to be capable of some kind of 'thinking'. In psychology, this revived interest in the internal processes of cognition in opposition to behaviourism. Learning theorists now look closely at the way that computers process information to build models about how human learning takes place. The transfer of information from outside and the way it is processed and stored in the brain seem to be very similar to the way that a computer functions. In education, a new idea about minds and machines developed – artificial intelligence (AI). If the computer can simulate the workings of the brain, then we can integrate computer programmes judiciously into our pedagogy to exercise the mind directly.

Consequently, cognitivists encourage the use of ICTs by teachers to consolidate new information and develop thinking skills. The role of the teacher is to instruct learners in thinking procedures, and designed computer software can be a great help to them in carrying out this role. Salisbury (1990) discusses two kinds of programmes on which cognitivists are particularly keen: (1) *drill-and-practise programmes* designed to consolidate knowledge, for example, software that enables learners to practise basic literacy skills, mathematical operations, spelling or grammar and (2) *thinking skills programmes* that aim to develop the strategic thinking processes that underlie all learning. Available programmes cover learners' skills in metacognition, inference from context, decontextualisation, information synthesis, etc.

It should be clear that cognitivism carries within it a significant notion of learner-centred instruction. Learning tasks must be presented to the learner in a way that they can access and understand them. Learners need to be supported in developing the thinking strategies that will allow them to gain such access. The requirement here is multifaceted. A cognitivist perspective on pedagogic integration looks to ICTs to provide a rich network of programmed resources for teachers to carry out the necessary instructional and support activities in the classroom.

Constructivism

Constructivism shares with cognitivism an interest in cognitive processes. It also stresses the need to understand these if we are to understand learning and teaching. Both reject behaviourism because of its denial of the mind. However, constructivism has a major disagreement with cognitivism. It does not think that the processes of learning are innate; rather, it insists that the knowledge and understanding of individual learners are *constructed* over time as they act on their environments and engage in social activities. Learning consists of the coordination of actions that are internalised in mental structures or operations (Richardson 2019).

The core idea of constructivism is well captured in this view of education put forward by Jean Piaget. He sees research on learning as divided into three distinct tendencies (Piaget 1969):

> The first [...] regards all knowledge as being externally acquired, as originating from experience or verbal or audio-visual presentations, delivered by adults. The second is characterised by a surprising return to innate factors and internal maturation [...] in this case, education becomes in the first instance the exercising of a 'reason' already formed at birth. The third tendency, which is decidedly our own, [...] is of a constructivist nature, that is to say, it is characterised neither by a notion of *external preformation* (empiricism) nor of *internal preformation* (innate ideas), but rather by a notion of the continuous elaboration of successive structures. (pp. 13–14; [*author's translation and added emphasis*])

The argument is straightforward. Behaviourism (with other kinds of empiricism) is static and bad theory; innatism is static and bad theory; good theory needs the idea of an interactive mechanism which constructs new understandings out of both existing knowledge and experience. Piaget's attack is on 'preformation', whether from outside or inside. He rejects the idea that when children learn, they passively receive knowledge.

Piaget explains that learning occurs through the developmental process by which we seek a state of equilibrium between our previous knowledge and new things we encounter in the world (Piaget 1968):

> Knowledge of an object does not consist of having a static mental copy of the object but of effecting transformations on it and reaching some understanding of the mechanisms of these transformations. [...] The fundamental relation is not one of simple association but of assimilation and accommodation; the knower assimilates objects to the structures of his actions (or of his operations), and at the same time he accommodates these structures (by differentiating them) to the unforeseen aspects of the reality which he encounters. (pp. 140–141)

We understand new things by *internalising* the consequences of our own actions as we seek a balance between the known and the unknown. Piaget's notion of *equilibration* conceives learning as the acquisition of an understanding of one's own intellectual operations – 'intelligence organises the world by organising itself' (Piaget 1975:355–356).

By the 1980s, Piaget's theory had come under severe criticism, mainly directed at the idea that his theory of stages of cognitive development should prescribe and proscribe curriculum for children. This led to a shift of attention away from these 'figurative' aspects of his theory to the 'operative' aspects, in what came to be known as Piaget's 'new theory' (Acredolo 1997; Amin & Valsiner 2004; Beilin & Fireman 1999). Contemporary Piagetian studies are firmly focused on the hard core of *equilibration* (Burman 2021; Winstanley 2021), not least in relation to the pedagogic integration of ICTs (Erneling 2010; Kaplan 2018).

The second major figure in the history of constructivism is Lev Vygotsky, who rejects behaviourism because it pretends that 'learning is development'.

He rejects innatism because it equates maturation with development: '*maturation* is viewed as a precondition of learning but never the result of it' (Vygotsky 1978:79–81). For him, an interaction between existing knowledge and experience explains learning as the construction of new knowledge (Vygotsky 1978):

> [*I*]nternal developmental processes [...] operate only when the child is interacting with people in his environment. [...] properly organised learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning. (pp. 90–91)

He therefore has much the same view of behaviourism and innatism as Piaget.

Vygotsky was interested in the way that human beings learn in social relationships with other people. This led him to investigate the importance of learning in schools or other educational institutions for our overall development as human beings in contemporary society. Learners develop new forms of understanding by *internalising* the knowledge that is initially constructed in joint social activity with the teacher (Vygotsky [1931b] 1998):

> [*T*]he child at first masters a purely external operation and transfers it into the sphere of his own behaviour in the form in which it is developed among people. He just unites in one person the two parts of the operation that were earlier divided between him and the adults around him. [...] the initial stage in the development of any higher function is the stage of the external operation accomplished through external means. Then, gradually, to the extent that it grows into the general structure of his thinking, it loses its external character and is transferred from outside inward and begins to operate mainly through internal means. (p. 104)

Vygotsky ([1934] 1987) emphasises how language provides the tools ('internally directed *signs*') on the basis of which learning takes place. The process of internalisation is based on the acquisition of *cultural means of signification*, which 'is initially a means of socialising and only later becomes a means of behaviour of the individual' (Vygotsky [1931a] 1997:103). He gives us insights into how spoken language allows teachers to mediate new forms of understanding to learners. For him, what is mediated are the symbolic systems of a culture or signs. Learning is the process in which these are *internalised* by the learner in the course of social activity. These pivotal constructivist concepts were formulated by Vygotsky in the 1930s and translated into the anglophone academic world in the 1960s and 1970s. They remain the core of contemporary Vygotskian studies (Falikman 2021; Gredler 2012; Miller 2011).

Piaget gives us insight into how individual *action* makes learning. Vygotsky provides insight into how this always happens in social *activity*. But the most important idea is common to both of them: no longer are children to be thought of as passive recipients of knowledge but rather as active constructors of their own knowledge in interaction with the world and society around them. They act on the world, and they learn from the consequences of those actions, which are internalised to become the forms of their individual cognition. New understandings are not simply given to children when they learn. For learners to be said to construct knowledge means both that they develop their own novel ways of knowing and that they acquire existing human knowledge (language, cultural wisdom, technical skills, school disciplines, etc.) as their systems of knowing.

Thus, constructivism works with the idea of *activity-based learning*. When we design learning environments according to these principles, we seek to create a sequence of learning tasks in which learners are required to engage in unfamiliar activities. They need to reflect upon those activities with support and ultimately internalise new understandings on the basis of those reflections. Piaget (1972) puts the principle of *active methods* in education thus:

> [*T*]o understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition. (p. 20)

This is the strong idea that constructivism has taken into the way we should integrate ICTs in the classroom. Often, we hear constructivists suggesting that the use of drill-and-practise software undermines the goal of active learning. Instead, they place emphasis on learning technologies for the classroom that enhance 'interactivity'. Examples of these include computer games, multimedia learning packages, hypermedia and virtual reality environments.

There is wide consensus (Hof 2020; Laurillard 2012:105; Lu et al. 2022; Watters 2011:259–260) that the best way to understand the influence of constructivism on the use of ICTs in education is to examine the work of Papert (1980). Although Papert later styled the 'ultimately political' process of constructing computational cultures in the curriculum as 'constructionism', he cautioned against 'simple catchy versions of the idea, […] for example, thinking of it as "learning-by-making,"' that lose touch with its essentially Piagetian epistemological and psychological elements (Harel & Papert 1991:1-2; Moll 2002:8ff; Papert 1980:5; 156 et passim).

Papert (1970:161) suggests that most uses of ICTs in education are tantamount to 'inventing new gadgets to teach the same old stuff in a thinly disguised version of the same old way'. He criticises three 'traditional' applications of computers in schools, which he tracks back to behaviourist roots:

- **The computer as an automated teacher:** Learning is viewed as a process of responding correctly to questions about 'a fixed body of discrete facts' and the attainment of strictly specified, predetermined behavioural objectives (Papert 1979:74–76).
- **The computer as a simulated world:** There is only an illusion of freedom for the learner to discover knowledge for themselves, as this is constrained by the predefined boundaries of a computer programme (Papert 1979:76–77).
- **The computer as a toy:** Restrictive computer languages that allow only the 'transmission of specific programming commands at specified times in the learning process' (Papert 1979:77–79).

Against this, Papert develops what he terms ‘a grander vision’ of computers in education: ‘In teaching the computer how to think, children embark on an exploration about how they themselves think’ (Papert 1980:19).

Practically, he developed the LOGO programming language in the 1980s to facilitate the active construction by children of their mathematical knowledge. LOGO employs a *microworld* to enable children to learn Mathematics ‘naturally and without conscious teaching’. Unlike programs that simulate preprogrammed and limited domains of cognitive activity, LOGO does not try to simulate an event or specific activity. Rather, it sets up a ‘conceptual system’ in geometry. Papert suggests that the logical structure of the programming language will encourage the construction of complex logical reasoning on the part of users of the microworld.

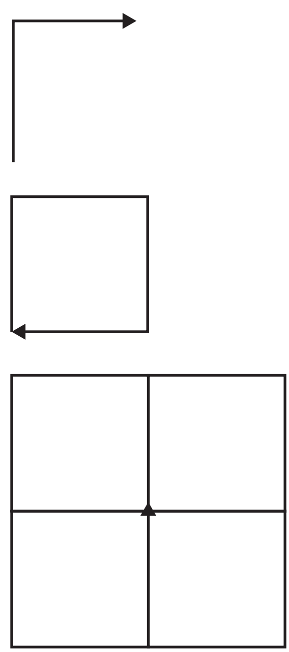
The device used in LOGO is a ‘turtle’ that the learners can command to walk around and leave a track. The idea is that they identify themselves with the turtle, plan and write commands about how it should move in two-dimensional (2D) space, and thus they actively ‘do’ geometry. The tracks that are produced are active constructions in which mental representations are translated into written mathematical commands. Then, they are tested against the geometric representations that are produced onscreen, as illustrated in Figure 1.7.

```
forward 100
right 90
forward 100
```

```
to square
forward 100
right 90
forward 100
right 90
forward 100
right 90
forward 100
end
```

```
square
```

```
repeat 4 times
square
end
```



Source: Adapted from Stenseth (2002:para. 10).

FIGURE 1.7: ‘Programming the Turtle’ in LOGO.

Papert (1980) also recognises the importance of the social construction of mathematical understanding. In the LOGO microworld:

> [*M*]athematics is a real activity that can be shared by novices and experts. The activity is so varied, so discovery-rich, that even on the first day of programming, the student may do something that is new and exciting to the teacher. (p. 79)

For a long time, LOGO has been regarded as an exemplary computer-enabled learning programme that embodies constructivist principles (Kahn & Winters 2021). Its key design feature is that it allows the learner to programme the actions of the computer world and not vice versa. In a number of ways, these constructivist ideas about the way that ICTs should be integrated into education prefigured the conception of interactive engagement with computer worlds that are now starting to be taken for granted with the advent of Web 3.0 educational technologies. To integrate ICTs into pedagogy is to employ the representational and other knowledge-related affordances of computers to present useful problems to children and to provide and guide them with means to actively engage these problems.

So individual action in the context of social activity is important for constructivism. But this does not mean that the teacher is unimportant. As Piaget (1972) puts it, in his idea of the teacher as a facilitator:

> [*S*]uccess [*does not*] depend on leaving the students entirely free to work or play as they will. It is obvious that the teacher as organiser remains indispensable in order to create the situations and construct the initial devices which present useful problems to the child. Secondly, he is needed to provide counter-examples that compel reflection and reconsideration of over-hasty solutions. (p. 16)

And Papert echoes the idea of the teacher as a mediator that we arrive at from Vygotsky: 'the LOGO teacher will answer questions, provide help if asked, and sometimes sit down next to a student and say, "let me show you something"' (Papert 1980:179). A constructivist teacher will employ computer-enabled learning programmes in her classroom to promote the conditions necessary for active learning to occur.

Thus, constructivism places the learner at the heart of learning. While the notion of learner-centredness is often mistakenly equated only with constructivism, the theory certainly does have a compelling account of an active, engaged learner at the centre of the learning process. The fundamental premises of constructivism are that the individual learner actively *builds* new understandings. Meaningful information and skills relevant to a learning task emerge within these built constructs rather than from the external environment or the acquired biological properties of the brain (Bruner 1990).

■ Socioculturalism

In the 1990s, a 'second cognitive revolution' occurred (Harré 1992). The impetus for this shift has been described as an 'all-out effort to establish *meaning* as the central concept of psychology – not stimuli and responses, not overtly observable behaviour, not biological drives and their transformation but meaning' (Bruner 1990:2; [*author's added emphasis*]). The important thing to understand about this 'revolution' is that it shifted the study of learning away from the idea that it is something that an individual does to the idea that it is, in the first place, a social phenomenon located in cultural practices and relationships between people. It drew a great deal from Vygotsky, particularly his idea that learning is socially constructed (Tzuriel 2021).

However, Vygotsky believed that we should emphasise that social processes are *internalised* to become the forms of cognition of the individual person. Strong advocates of sociocultural theory have dispensed with the need for an individual, psychological account of learning. In this sense, the theorists of the 'second cognitive revolution' have moved beyond constructivism in their attempts to understand learning. Wertsch (1991, 1993), for example, suggests that we should use the term *mastery* rather than internalisation to describe learning. He thinks that phrases like 'internalising a skill', 'internalising a concept' or 'internalising a structure' reduce the sociocultural locus of cognition to a property of an isolated individual. In a direct criticism of Vygotsky, he asks, 'What is lost by speaking of mastering a skill, concept or structure? [...] The only thing we lose is an implicit commitment to an unwanted set of [individualist] assumptions' (Wertsch 1993:169).

In opposing the notion of the mind as an internal centre of cognition, socioculturalism of course also opposes cognitivist assumptions about learning. As Hutchins (2006) puts it:

> [*C*]ognitive science made a fundamental category error when it mistook the properties of a person in interaction with a social and material world for the cognitive properties of whatever is inside the person. (p. 1)

Contemporary socioculturalism is sustained in this denial of internal mental processes (Ferreira 2020; Veresov 2020).

Three important ideas that go with this sociocultural approach to learning are the related concepts of *collaboration*, *distributed cognition* and *situated cognition*. Collaborative learning is construed as a process of growing up and participating in a community (Sfard 1998). It takes place through social interaction, negotiation and shared practices of meaning-making in joint problem-solving activities. Socioculturalism emphasises and seeks to model the knowledge practices and discourses in any community on the understanding that the locus of learning *is in those practices*. A broad family of theories can be considered to fit under this description. Some that we often hear mentioned in relation to collaborative learning are:

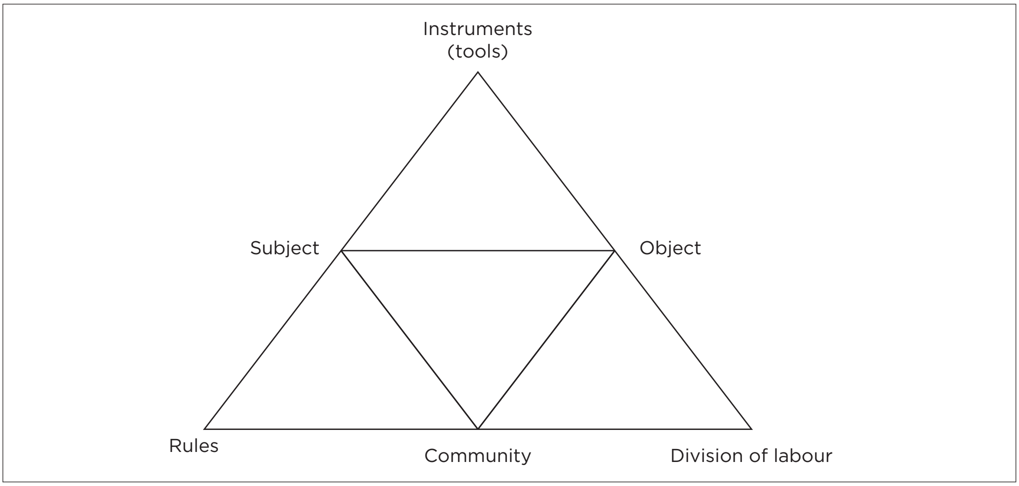
- Learning organisation theory, which conceives of an organisation as the entity that learns collaboratively rather than adopting the more modest

constructivist position that an organisation provides the social and cultural conditions within which individual learning takes place (Senge 1998).
- The theory of communities of practice, which seeks to describe the collaborative, social learning processes among people who participate together in a shared profession, occupation, craft or interest group (Wenger 1998).
- Activity theory, which conceives of the mind as distributed across an activity system (see Figure 1.8) that creates the collaborative possibilities and constraints for human endeavour (Engeström 1987).

These theories all share the view that the mind is 'distributed' across the body, cultural artefacts and social relations. To help understand them, we might consider the following question (Bateson 1972):

> Suppose I am a blind man, and I use a stick. I go tap, tap, tap: Where do I start? Is my mental system bounded at the handle of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of the stick? [...] If what you are trying to explain is a given piece of behaviour, such as the locomotion of the blind man, then, for this purpose, you will need the street, the stick, the man; the street, the stick, and so on, round and round. (pp. 458–459)

The notion here is that the 'mind' is *not* an individual thing. Nor can it be understood to be bounded by the human body; it is not, so to speak, 'under the skin'. Rather, the suggestion is that the mind is *distributed* across all the different entities that make up any human activity. It is contained in the tools that we use (e.g. the stick), the culturally-defined space that we live in (e.g. the pavement) and in the social relationships between people in which knowledge



Source: Engeström (1987:136).

FIGURE 1.8: Engeström's conception of an activity system.

is constructed. When we focus only on the individual learner, we lose sight of the fact that we always think by means of cultural symbols, artefacts and practices. Learning is necessarily embedded in cultural practices. It is, to use the going theoretical term, *situated*.

Collaborative learning is the core socioculturalist e-learning principle. The broad terrain of distributed and situated cognition theory has significantly influenced our understanding of the learning affordances and potentials of modern educational technologies. Crook ([1994] 2017) has described five modes of social collaboration made possible by computers. These show various learning affordances that the integration of ICTs brings into the classroom (he devotes a chapter to each one of these in his book):

- **Collaborative interactions with computers:** The physical presence of ICTs provides opportunities for critical classroom discussions.
- **Collaborative interactions in relation to computers:** '[C]omputers can become an activity setting in relation to which common knowledge is effectively negotiated' (Crook [1994] 2017:118–119).
- **Computer-based peer-collaboration:** Computers provide a medium for collaborative work.
- **Collaborative interactions at computers:** '[T]he design of computers [...] demands a narrow focusing of attention and action. [...] [Their] powerful graphic capabilities [support] shared reference amongst pupils [...] as they collaborate' (Crook [1994] 2017:186).
- **Collaborative interactions around and through computers:** '[A] transient learning community [...] might collaborate "through the air"' (Crook [1994] 2017:190).

One reason why collaboration is at the forefront of such ideas about learning is the ubiquity of the Internet in education with computers. Modern computers tend to be networked with each other, so they encourage learning activities that are very much about collaborative interaction. We now live in a world in which networked, digital technologies – computers, mobile telephones, television, satellite technology, etc. – have dramatic implications for the way we think and learn.

Within the broad parameters of socioculturalism, we find connectivism, an ostensibly new 'learning theory' developed by Siemens. It is significant because it is intimately connected to computer culture and e-learning. The theory claims to be 'a learning theory for the digital age' (Siemens 2005). It regards learning as distributed across mind, machine and the networked society – 'learning is the network'. Connectivism dislikes what it perceives to be outdated, pre-digital age theories of learning (Siemens 2005):

> Behaviorism, cognitivism, and constructivism are the three broad learning theories most often utilised in the creation of instructional environments. These theories, however, were developed in a time when learning was not impacted through

> technology. Over the last twenty years, technology has reorganised how we live, how we communicate, and how we learn. Learning needs and theories that describe learning principles and processes should be reflective of underlying social environments. (p. 1)

Like other distributed cognition theories, connectivism locates learning socially rather than in the individual. The ubiquity of networks of information, networks of computers and other digital technologies, and networks of people linked together in unprecedented ways by technology provide the social context of learning. The theory considers learning to be the development of 'conversations' within web-enabled spaces – podcasts, blogs and social media like Twitter, Facebook and Instagram are conceived as the primary learning environments of the modern world. To bring education centrally into the space of learners means that we must integrate the virtual worlds of conversation and exploration of knowledge enabled by ICTs into the centre of the learning processes of the school. As Siemens (2009) puts it:

> [*T*]echnology has enabled our generation to externalise – through video, pictures, audio, text, and simulation – our ideas. Once externalised, a trail of identity and conceptual development is left for future consideration and analysis.[4] (n.p.)

Ironically, like behaviourism, these views suggest the teacher has less and less of a role to play in learning. Advances in modern digital technology are likely to lead to computers taking over the primary role of working companion and teacher for the child (Light & Blaye 1991:215). So the *human* teacher is conceived as something like a manager of collaborative learning environments. Pedagogic integration is not instruction, facilitation or mediation, as the cognitive theories would have it.

■ Embodiment

The recent field of embodied cognition might be conceived as psychology bringing the situated body back into the picture (Wilson 2002). Its central claim is that we learn through direct bodily engagement with the world. New understandings arise in our awareness of our physical, sensing body as the source of learning. This idea goes back to the phenomenological notion of *being-in-the-world* (Merleau-Ponty [1962] 1996):

> My body is geared onto the world when my perception presents me with a spectacle as varied and as clearly articulated as possible, and when my motor intentions, as they unfold, receive the responses they expect from the world [...] [*This is*] the basis of my life, a general setting in which my body can coexist with the world. (p. 250)

Merleau-Ponty's view is that the human body serves as 'the context or milieu of cognitive mechanisms' (Lakoff & Johnson 1999:xvi). Our body exists

4. There is some sort of ICT hubris in these words. Writing has for thousands of years been the pre-eminent technology through which we human beings have systematised and externalised our thinking. This has not ceased to be the case with the advent of digital ICTs. On this, see Wolf (2008).

primordially before there is thinking or any representation of the world. Embodied learning involves being attentive to the body, its experiences and transformations. It is a way of knowing that is 'grounded in and through our bodies' (Lakoff & Johnson 1999:6).

One interesting route back into this phenomenology is through the psychiatric writing of Frantz Fanon, who suggested that the experience of colonial domination by colonised people was often internalised by them as their own state of *being-in-the-world*. As he put it, 'it is the outcome of a double process [...] primarily, economic [...] subsequently, the internalisation – or, better, the epidermalisation – of this inferiority' (Fanon 1967:11).

One can see the affinity here with Piaget and Vygotsky on *internalisation*, discussed earlier. For Piaget, learning takes place when learners internalise the consequences of their actions as the transformed structures of their own thought. For Vygotsky, learning is the internalisation of the structure of what is originally a social relationship of mediation between a teacher and a learner to become the learner's own thinking. The notion of internalisation into the body of thinking and action is an important aspect of embodied learning theory.

My view is that bringing together Piaget and Vygotsky (as constructivists) with embodied cognition theory resolves a dilemma in learning theory. The radical parts of constructivism are the emphasis on action on the world as the source of knowledge and the idea of learning as the psychological internalisation of those actions. The dilemma that Piaget and Vygotsky never seemed to resolve is internalisation into what? Fanon's theory of epidermalisation provides the answer – internalisation into the body or embodiment. So the idea that there is continuity between constructivism and embodied cognition theory lies in a synthesis of Piaget, Vygotsky and Fanon.

Embodied cognition theorists challenge the cognitivist conception of cognition as disembodied mental representations. They suggest that learning is adaptive behaviour rather than abstract information processing (Heras-Escribano 2019; Thompson 2007). So learning should be understood as the emergence of increasingly complex cognitive processes from 'continuous sensorimotor interactions involving the brain, body and environment' (Thompson 2007:10).

An important dimension to this understanding of embodiment is provided by Damasio's (2000, 2006) work on the relationship between cognition and affect in learning. As human beings (like any other animal), we are engaged with the world as bodies situated materially in it. This engagement is always emotional – its core is a set of actions and reactions that have been deeply coded into us by our evolution over millions of years, sometimes known as the 'four Fs' (feeding, fighting, fleeing and mating). However, as a highly evolved species, we experience this engagement cognitively, in what we call 'feelings'.

Feelings are images of our emotions in our thinking. Furthermore, we build elaborate cognitive constructions on top of our feelings and thus deliberately regulate them for various purposes (primitive animals cannot do this – they simply act emotionally). Thompson (2007:11) sums up this movement beyond cognitivism succinctly: 'the central metaphor for [the embodied cognition] approach is the mind as embodied dynamic system in the world rather than the mind as neural network in the head'.

It follows that embodied cognition theory continues to place emphasis on the situatedness of most learning in the social and cultural environment. The mind is situated in tool usage, in artefacts, in spoken language, in society and in culture. However, to say that it is situated in the social environment is not to say that *it is social* (Wilson 2002). Mind is embodied and situated, in the sense that both the body and surrounding environment play an essential role in explaining learning (Heras-Escribano 2019). Embodiment is a necessary condition for psychological activity, and so this theory moves against the denial of internalisation associated with socioculturalism (Damasio 2006; Johnson 1989; Wilson 2002). Embodied learning theorists do not think that *the mind* is constituted in elements that exist outside of the human being (Wilson 2002). It is not distributed across the brain, the body *and* tools, artefacts, texts, culture, et cetera and neither is learning. It is distributed within the body; it is indeed 'under the skin' or epidermalised.

Macedonia (2019) describes traditional teaching, in which ' school learners sit, watch, listen, and write', as the false separation of mind and body – both behaviourism and cognitivism rely conceptually on this dualism. Macedonia presents embodied learning as a pedagogical practice that reunites body and mind. As teachers, we use our bodies to convey knowledge to our students (see Johnson's 1989 'language of practice' metaphor). To teach is to elaborate cognitive knowledge on top of these bodily representations. The conscious use of modelling, gestures and embodied simulations are good examples of this. There is also a myriad of nonconscious movements, gestures and facial expressions that we constantly employ as we teach. Reciprocally, students also use their bodies to enact new learning by imitating[5] the teacher's representations; so, on one level of communication between them, teaching is *visceral*. Learners (including teachers learning about their own teaching) construct and elaborate on new understandings (i.e. reinvent or, in rare cases, invent knowledge) on the basis of their bodily representations of the world.

Embodied learning is realised in formal learning by means of 'haptic technology'. Examples include gesture-based computing and augmented

5. 'Imitation' in learning is often thought about, unhelpfully, as something like the replication or mirroring of a teacher's words or actions. In the terms of embodied cognition, however, it refers to action on the part of a learner to reconstruct the lived experience of another individual, or in bodily terms, to reactivate the sensorimotor circuits associated with a learning object (Soylu et al. 2014:3).

reality displays (Fugate, Macrine & Cipriano 2019:283). Lindgren et al. (2016) show how computer-enabled, whole-body simulations of concepts like gravity and planetary motion produce greater engagement and positive attitudes towards science. Macedonia and Knösche (2001) show that adding metaphorical gestures to words in video and audio presentations enhances semantics. The use of avatars in digital learning spaces to enable *perspective-taking* is also a significant embodiment of learning. Soylu et al. (2014) look back to Papert's LOGO as pioneering work in this area. Specifically, embodied learning is evident when a child moves a cursor to 'think like a turtle' to program a computer. Papert (1980) himself describes this activity as *body syntonic* because it entails movement in real physical space to draw shapes on the computer screen. There is increasing contemporary interest in instructional avatars based on embodied learning theory (Cook et al. 2016; ed. Schroeder 2002).

Notice how the embodied cognition theory also works with a clear notion of learner-centred pedagogy. Education is about building the elaborate cognitive constructions of human knowledge and culture but always on the basis of emotions that drive the *internalisation* of this knowledge. 'Embodiment' emphasises that our emerging complex mind, much more than emotion, is nevertheless seated in our emotions.

■ Conclusion

The five theoretical perspectives discussed have contrasting emphases in considering the pedagogic affordances of ICTs in education (see Table 1.1). They start in different places, and in the end they emphasise radically opposed priorities related to classroom learning. Yet they also can be thought of as complementing each other, providing a rich set of practical ways to integrate computers and other technologies into our classrooms. The most important issue for teacher education is that theories of learning provide insights to ensure that student-teachers graduate with a strong understanding of how to use ICTs to enhance learning and teaching. Too often, they are taught only technical information technology (IT) skills, such as how to work with Microsoft Word, LibreOffice spreadsheets, Microsoft PowerPoint, Google Docs or a Moodle learning platform. If teacher educators regard different learning theories as discrete 'paradigms', then they have little choice but to do this. They can either just hope that their new teachers will somehow fill in a learning theory for themselves, or they can teach these skills through the medium of just one of the theories of learning, knowing full well that they have made an 'ironic' choice, against their better beliefs in epistemological relativism.

TABLE 1.1: Overall features of learning theories with respect to the pedagogic integration of ICTs in the classroom.

Learning theories	ICT integration metaphor	Key learning concepts	Learning design principle	Concept of learner-centredness	Instructional role of the teacher
Behaviourism	Computer-based education	Reinforcement Shaping	Programmed instruction	Learners proceed at their own pace	Manager of reinforcement contingencies
Cognitivism	Computer-aided (computer-assisted) education	Hard-wiring Information processing	Systematic instruction (e.g. drill-and-practise)	Learners have inborn possibilities and constraints as thinkers	Instructor of thinking procedures
Constructivism	Computer-enabled education	Action or activity Internalisation	Activity-based learning	Learners actively construct their own knowledge	Facilitator and mediator
Socioculturalism	Web-enabled education	Social participation Externalisation	Collaborative learning	Learners form their identity in virtual communication	Manager of collaborative online learning environments
Embodiment	Computer-afforded education	Internalisation or epidermalisation Expertise	Embodied learning tasks	Learners are situated and emergent bodies	Facilitator and mediator of embodied learning

Key: ICT, information and communication technology.

However, if they treat learning theories as moments in the historical progression of ideas about learning, then they can teach the pedagogical integration of ICTs in a conception that draws on all the theories along these lines:

- A learning programme afforded by computers should be carefully sequenced, taking a learner step-by-step towards the achievement of required outcomes (a central idea drawn from behaviourism).
- It should provide systematic opportunities to foster and support memorisation and other thinking strategies and be designed in such a way as not to overload students cognitively at any point of engagement (an idea from cognitivism).
- It should contain a series of constructive learning activities, which might be strongly guided by the teacher or minimally guided, depending on the verticality of the knowledge discourse of the task (see Bernstein 2000:155–174) (an idea from constructivism).
- It should provide some opportunities for exploration of the Internet in collaborative activities with fellow students (an idea from socioculturalism).
- It should provide embodied representations by the teacher of knowledge required to complete the activities, by the learners as they present their work to peers and for assessment (an idea from embodied cognition theory).

These might be thought of as five big ideas for novice teacher educators to take with them into their first classrooms. This is, I suggest, the most educative way that a teacher educator can work with theories of e-learning. It is crucial that student-teachers understand that the pedagogic integration of ICTs into the classroom goes with an understanding of what learning in digital space is. Failing that, they fall back on much of the prevailing nonsense that ICT adoption by schools will automatically, somehow magically, bring more effective and expansive teaching methods with it.

At the same time, there is neither the time nor the scope within a teacher education programme for students to study the in-depth implications of any one theory of learning as it applies to digital learning – that is, for the students' postgraduate years. Working with these various theoretical insights of different theories in this way, they become compatible *in the context of a particular e-learning lesson or project*. The deeper epistemological and ontological issues remain, but because we are working with an understanding that the development of learning theory is the accumulation of explanatory hypotheses over time, we can work with them in this pragmatic way for purposes of teaching and teacher education.

This is perhaps what the psychologist William James (1899) had in mind some 120 years ago, when he warned of the danger of believing that any theory of learning can provide us with a recipe for effective teaching practice:

> You make a great, a very great mistake, if you think that psychology, being the science of the mind's laws, is something from which you can deduce definite programs and schemes and methods of instruction for immediate schoolroom use. (n.p.)

The caution seems no less pertinent today, perhaps in particular for the teacher educator. James' pragmatic maxim was that teaching is not the straightforward application of learning theory, but it does entail the ability to draw on this theoretical knowledge to strategise and reflect on one's teaching at appropriate times. In the context of the pedagogic integration of ICTs in our schools, e-learning is not about the straightforward application of new learning technologies in the classroom. The suggestion in this chapter is that to approach theories of learning and the affordances of technologies of e-learning in the classroom as a progressive history of ideas is the most productive way to develop ICT-related teaching know-how in our education students and for them to integrate ICTs into their emerging pedagogies.

Chapter 2

Computers and care? How can ICT integration help to build supportive PLC in ITE?

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Abstract

This chapter explores how information and communications technology (ICT) integration can aid the building and establishment of supportive professional learning communities (PLCs) in initial teacher education (ITE). It argues for an approach that foregrounds an ethic of care, community and collective well-being that signals a shift away from managerial discourses. I use Margaret Archer's concepts of structure, culture and agency to theorise and analyse ICT integration as a way to establish PLCs and offer some considerations for teacher professional development (TPD). The argument is that a reimagining of TPD involves going beyond effectiveness and efficiency discourses to ones that involve cultural work, having social justice ideals, transformation and redress at their core. It goes further to argue that ITE and ICT integration is about not only improving existing teaching practices but rather focusing on transforming them. The notion of troubling our own thoughts involves notions of learning and knowledge and shifting away from purely Western ideas of

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individualism towards views that advocate collective rather than individual agency. It recognises that university teachers are part of the same struggles that communities face and thus need care. This ethic of care could link the schools that *are* with the schools that *should (could) be*.

Introduction

Taking into account the rapidly changing nature of education around the world, as well as the South African context, PLCs are necessary, now more than ever, in TPD. Given the urgent need for socially just education, PLCs are essential for the ongoing cultural work of TPD. While the COVID-19 pandemic – and the rapid infiltration of ICTs into education, which had begun long before COVID-19 – is isolating us from each other, the discourses around ICT implementation in education often celebrate the individual hybrid-flexible or 'hyflex' learner, rather than a sense of community, collective agency and the power of the collective.

Hence, in the midst of the COVID-19 pandemic, with buzzwords such as un-grading, un-schooling and un-bundling circulating, integrating ICTs into teaching and learning has become a priority. While the prevailing discourses around ICT in education focus narrowly on 'effectiveness' or 'efficiency', I argue for ICT integration that takes the form of critical pedagogies fostering community building and care. In my view, facilitating a process of change regarding ICT implies a move away *from individualism towards the collective*. Thus, it is worrisome that some current ITE offerings do not sufficiently take into account *agency* in enacting, using and deploying ICT integration for learning and teaching.

The focus of this chapter is on how fostering the PLCs among student-teachers that form the basis of their TPD is possible using ICT integrated within teacher training. The proviso is that digital technology is used to offer learning experiences and practices that foreground an ethic of care, community and collective well-being. Such an ethic is not often acknowledged in managerial discourses within education, particularly those around technological 'innovation'. To discuss PLCs, I draw on Wenger's (1991, 2009) work around communities of practice (CoPs) and social learning spaces, combined with Archer's (2000) social realist concepts of culture, structure and agency. I will show that student-teachers and the teachers who train them need to be supported to use their agency (as collectives or PLCs) to both navigate and shape the culture and structures of the educational institutions and systems within which they work, to reorientate these institutions towards an ethic of care. Given that ICTs are increasingly a central means for teaching and learning, I focus on how these ICT tools can be integrated into teaching so as to foster collective agency. This theoretical chapter thus explores the implications for the role of teacher-training schools or departments in offering authentic technology experiences and practices, that is, modelling the kind of ICT-enriched teaching that student-teachers should ideally emulate. What is envisioned is a radical shift away from discourses that frame the ideal teacher as a 'competent' or 'effective' and 'efficient' user of technological tools or as a digital nomad who individualistically learns to navigate networks and respond to the economy. Rather, the shift I am proposing is to envision teachers working together as collective agents (PLCs) who use ICTs to make the world a better place for all (Macgilchrist, Allert & Bruch 2020).

In this chapter, I explore PLCs – also known as CoPs or social learning spaces – and their roles in TPD. I then unpack the role of ICTs in the ongoing process of educating teachers, which is known as TPD. I briefly set out social realist concepts as a theoretical and analytical lens. Following this is a short discussion of ICT integration in the classroom. Next, the focus shifts to fostering connection and care and resultant enablement, constraints and offers a practical example. The chapter ends with a challenge to do better in preparing preservice teachers – as a collective or PLC – for the complexities of the real world.

■ Personal learning communities

A PLC, also known as a CoP, can be conceptualised as a group of people that come together to share cultural practices (Lave & Wenger 1991).[6] Negotiated identities form and are shaped in the process. Personal learning communities are characterised by a *domain* (shared interest or purpose, specific rules of engagement), a *community* (shared sense of community and trust for relationship building) and *practice* (context-specific, shared methods and tools).

A PLC generates occasions for deep and meaningful engagement and the sharing of approaches and practices. In essence, PLCs develop over time and are not events but rather processes, hence the inadequacy of once-off workshops or courses. Boud and Brew (2013:213) argue that practices 'evolve over time and over contexts: new challenges require new ways of practising'. Within a PLC, the student's sense of agency is central: a study of continuous professional development (CPD) by Schostak et al. (2010) found that CPD as led by students was the most valued, suggesting that members of a PLC want to decide on the form their engagement will take. This study also found that the sustainability of CPD depends on the extent to which individual students' needs are met.

6. Wenger (2009) later proposed a more inclusive, revised conception of CoPs, known as social learning spaces (SLSs). Social learning spaces are: '[...] social containers that enable genuine interactions among participants, who can bring to the learning table both their experience of practice and their experience of themselves in that practice' (Wenger 2009:3).

Building a PLC can therefore be a challenging task. The theoretical literature on PLCs often ignores problems such as power differentials (Smith [2003] 2009), the competing goals of group members that could limit participation (Roth 2001:1002) and the effect of cultural and historical context (Engeström 2007; Jewson 2007). In practice, PLC formation often happens organically (Lave & Wenger 1998), and the PLCs that form are not necessarily creative or innovative, but can also function to defend or maintain existing practices rather than bringing change (Edwards 2005 in eds. Hughes, Jewson & Unwin 2007). Agherdien and Petersen (2016) report on a study that tried to implement social learning spaces, emphasising the complexity of the task and the numerous tensions encountered, principally the difficulty of developing students' agency and dealing with power differentials. These challenges demonstrate that despite how simple PLCs can seem in theory, implementing such learning needs careful and intentional engagement with the community in its context and the students' own lived experiences (Freire 1972).

The role of information communication technologies in teacher professional development

Teacher professional development falls within the broader category of academic development (AD), also known as professional development (PD), which as Stensaker (2018) argues is a form of cultural work:

> Cultural work can be defined as a deliberate attempt to develop and disrupt the organization on the basis of established and emerging practices and knowledge. It follows from this definition that cultural work should be seen as both constructive and critical: as a rather dynamic process guided by the need sometimes to question formal objectives and goals, as well as established traditions and historical practices. (p. 277)

Teacher professional development as cultural work therefore goes beyond *improving teaching* (Zembylas 2017) and involves embracing student-teachers' agency, connecting with and meeting their needs and perspectives as students and enabling them to do the same as teachers. Further, for teacher education institutions, I would argue that TPD involves disrupting the institution's own approaches and practices to keep the institution moving forward in its service to the community.

My core argument is that the issue of practice teaching (also known as service learning) calls for exposing teachers to 'knowledge *of* and knowledge *from* teaching'. This is where the ethic of care must guide TPD to link the schools that *are* with the schools that *should be*. However, the predicament relates to (Esau & Maarman 2019):

> 'The Learning Outcome Dilemma' – should teacher education programs prepare teachers 'for the schools that are or the schools that should be'? We maintain that

> teachers must be equipped for both. Teachers must first be able to function in the schools that are. However, we also need to prepare 'transformative agentic teachers' (Orland-Barak 2017:250) who would be able to work in diverse environments, pursue social justice in education and negotiate the increasing complexity of a fast changing world. (p. 3)

Teacher professional development is particularly challenging to imagine in the South African context (Bali & Caines 2018), because of difficulties such as an articulation gap between the education teachers receive and the reality in which they work; a chronic lack of mentorship for young teachers within the education system; and the trying conditions at schools (Gravett, Petersen & Ramsaroop 2019). There is a perception that ITE does not prepare teachers for the varied roles they will play, which range from teaching and being assessment specialists, course designers and curriculum developers to caregivers and active citizenship promoters; the requisite support structures are not in place (Esau & Maarman 2019). Dlamini and Mbatha (2018:28) emphasise that TPD support must be context-specific, 'because teachers' lived experience can help in designing meaningful' activities in an ongoing way (not once-off courses or workshops). Hence, more flexible, customised TPD opportunities are needed to effect social change (Bali & Caines 2018). Using ICT integration that fosters PLC to engage in approaches and practices of the discipline, connection and care that disrupt existing ICT effectiveness and efficiency discourses are what should ideally direct ITE preparation and TPD.

In March 2020, the rapid move to emergency remote teaching and learning (ERTL) – or a move to online learning as a modality – was accompanied by frustration, angst and unease (Czerniewicz et al. 2020; Jansen 2020). The move created numerous challenges for all and warranted 'education to be an act of care' (Daniels 2020:134). The challenges included feelings of isolation – both physical and emotional by academic staff and students alike – moving support and AD and professional learning opportunities online, teaching staff's readiness to design pedagogically sound online courses and last but not least, loss of work-integrated learning or practical work. Despite the challenges, networks of care[7] were formed (Czerniewicz et al. 2020).

My view of care resonates with that of Rasool (2020) as being integrated across religion, time, contextual factors and practices. Care is thus not restricted to a particular faith. It encompasses moderation (no place for extremism), gentleness, compassion, calmness and kindness to all, as was embodied by the Prophet Mohamed (Peace be Upon Him). In Rasool's (2020) words, care in Islam is seen as:

> [*A*]n integrated approach to human problems. Within the Islamic perspective, the concept of care is regarded as a spiritual dome where the basic needs of the

7. Networks of care refer to students and lecturers alike sharing resources such as laptops and data and generally checking in on each other regularly to offer help and support.

> [*persons*] are met according to the Holy Qur'an and the statements (Hadiths) of the Prophet (PBUH). Islam is a natural religion applicable to Muslim and non-Muslim communities. It is fully capable of fulfilling the needs of the time and satisfying the demands of new circumstances without any changes in religious beliefs and practices. (n.p.)

While the formation of networks of care moved us closer to a more human and humane approach, the discourses (e.g. the United Nations Educational, Scientific and Cultural Organization [UNESCO] framework) remain focused on equipping graduates with digital competencies and skills, neglecting the much-needed connection and care. I would argue that if higher education institutions (HEIs) want to produce this (caring) kind of teacher, and they have to do it using ICTs, then technological tools have to integrate pedagogy in particular ways. These ways privilege relationships and, therefore, a sense of communal agency. These are the 'competencies' student-teachers should experience and then be able to implement themselves in their use of ICTs in schools. Such agency will drive the continued social learning, support and care that should ideally comprise TPD.

With this shift in mind, fostering and maintaining relationships among students and between students and lecturers have become central. To support this relationship building, one option is to encourage the formation of PLCs using ICTs (more about this in a later section).

Another option is *empowering students* to take control of their learning (as *collectives* or PLCs) and use their *agency* to navigate learning spaces. Placing the focus on learner agency is a deliberate attempt to drive social learning and serve as a mechanism for connection and care. Notwithstanding the benefits of social learning, Veletsianos and Navarrete (2012) in their study concluded that learners do not always interact with one another beyond course requirements. Still, the diversity of learners coupled with the university settings and the wider world compel a kind of TPD – understood in all its complexities – that can foster social learning spaces. Notably, the purpose of ICT integration in ITE programmes is not solely to equip graduates with the appropriate competencies and skills needed to cope with the fast-approaching digital world (UNESCO 2011) but also to foster connection and care (through PLCs) and more so to make positive contributions to the lifeworlds of all.

Theoretical and analytical framework: Through the lens of social realism

To understand how TPD as a meaningful change can be accomplished under conditions that require ICT to be integrated into teaching and learning, a theory of change is needed to explore how PLCs can act as generative mechanisms to shift pedagogy. Such a theory is Margaret Archer's social realism (1995, 2003, 2013). One way to view a mechanism is 'a causal structure', usually unobservable, 'that explains an empirical outcome' (Bygstad, Munkvold & Volkoff 2015). Boughey and McKenna (2021) describe a mechanism as being both physical as well as social in nature. Where social realism could be especially useful is in uncovering mechanisms that enable or sometimes constrain participation and action.

In short, *structures* refer to tangible things such as policies, rules, guidelines, etc., while *culture* is something intangible (e.g. the way things are done at the institution). *Agency*, on the other hand, refers to the freedom to choose or having a voice. The interplay between these three can be enabling or constraining. For example, if students have collective agency (freedom of choice), and the institutional structures or policy supports that freedom, a transformative culture is enabled. Conversely, the individual might have agency, but the culture or the structure could constrain the individual agent from acting.

Archer (1995) offers agency as a generative mechanism to enact social change (where the change could be either structural or cultural). Archer (2013) calls this *morphogenesis*, a change over a historically situated period of time underpinned by a certain purpose. Important to note is that agency could be at the individual level or at the collective or group level, and the interplay between the two is significant. An individual might not act alone (for example, based on concerns or emotions) unless they have the backing of the group (or collective agents, as there is safety and power in numbers).

Thus, agency in the collective sense could refer to the PLCs' personal learning networks (PLNs) people belong to, for example, institutions that have the same structures, cultures and opportunities, but the mediation of individual agency (Archer 2003) is core. Thus, agency is at once individual as well as collective and can shape why and how institutional culture (beliefs, values and practices) and structures (roles, rules, institutions, systems and policies) are recognised. Constrained by hegemonic structures and cultures (such as the power differentials within ITE programmes or education schools), the changes could be characterised by big shifts, which Archer calls 'elastication', or small shifts known as 'limited expansion' (Archer 2003:148).

■ Towards information communication technology integration to foster professional learning communities

Numerous studies have explored how ICT in education is conceptualised, practised, supported and researched (see Agherdien, Henning & Van der Westhuizen 2007; Dlamini and Mbatha 2018; Henning & Gravett 2021; Lautenbach 2008; ed. Veletsianos 2010). There is a general perception that the ICTs in education debates have become progressively critical, that is, beyond adoption questions (Agherdien & Pillay 2020; Bali 2020; ed.

Veletsianos 2010) to a move to 'opportunities for relevant and meaningful transformation'[8] (ed. Veletsianos 2010).

I explore how digital classroom technology fosters connection and care and so builds towards PLC establishment. In a post-COVID-19 world, learning needs to continue – albeit in reimagined ways – and therein resides the opportunity for ITE programmes to model to preservice teachers how to integrate digital technology in contextualised, critical and adaptable pedagogically sound ways. Henning and Gravett (2021:189) posit that 'teacher educators had to live the change for which they had been training student-teachers from the lectern and in practicums'. In essence, the ICT integration proposed is one where teachers use the tools in a way that gives access to anyone anywhere in the world, but beyond physical access, it also provides opportunities for PLC formation. Such PLC formation could be fostered through ICTs as tools for collaborative engagement, critical dialogues and transformed experiences and relationships – ongoing beyond the TPD. It further involves engaging 'work to which we must bring our full selves, and work to which every learner must come with full agency' (Henning & Gravett 2021:236). What this implies is the pedagogical use of online tools such as discussion forums (for asynchronous discussions), social media (e.g. Twitter and Facebook) and Microsoft Teams (for synchronous discussions) to build PLCs. I will discuss technological tools briefly in terms of enablement and constraints.

Fostering connection and care: Information communication technology enablement, constraints and practical examples

This short section proposes the ICT tools as enablers of fostering dialogic encounters towards PLC formation. If used as tools to foster dialogue, connection and care, discussion forums, social media and Microsoft Teams can be quite powerful. However, when using ICTs in technicist ways (e.g. to ask students to describe, list items or facts, etc.), then it becomes a counterproductive exercise. I consider the question: how might we use the ICTs to engage PLCs in conversation and debate with others (that is, connecting locally and across the globe)? Another question for consideration is: how might we encourage safe spaces for dissent in caring ways?

Enablement

The discussion forum tool is good for fostering asynchronous connections. According to Agherdien et al. (2020), knowledge is constructed in interaction

8. Veletsianos refers to transformation as changing from traditional, structured tool usage to a more flexible model that is adaptive to students' needs.

with other or multiple viewpoints or perspectives in two-way conversation or dialogue. Further, students have the opportunity to evaluate responses for their validity and, in so doing, have 'interpretive authority' (Wilkinson 2009) or agency in a social realist sense. The collective learning that happens through sense-making or connection (Herrington et al. 2010; Lave & Wenger 1991) could be generated via the forums tool and, by implication, could foster the establishment of PLCs. However, careful tool usage underpinned by sound pedagogical considerations and critique are key.

Garrison and McInnes (2005) maintain that from an 'access perspective, participants are able to maintain engagement in a community of learners when and where they choose' through what they call communication and Internet technologies. They further argue that the interaction should be varied and sustained and:

> [/]t is valuable and even necessary to create a community of inquiry where interaction and reflection are sustained; where ideas can be explored and critiqued; and where the process of critical inquiry can be scaffolded and modelled. Interaction in such an environment goes beyond social interaction and the simple exchange of information. (p. 134)

That is, while the physical tools enable engagement, the activity design, manner of support and modelling are the generative mechanisms that enable and add *value* to PLC formation. I would add that the context in which PLCs are embedded has a bearing on the value creation ICTs hold for PLCs. Social media enable connection and, if used intentionally, care and community building beyond borders (Lee & McLoughlin 2010). Having dialogues with others via social media outside of the community could strengthen the PLC.

Further enablement could be strengthened through education as an act of *care*, as Daniels (2020:134) suggests, and requires effort (dedication) to connect students, whether it be through physical contact, synchronous or asynchronous. Adding value through care (for and about) means including in ITE teaching the process of and rationale for being caring (Anderson 2018). In turn, this implies integrating ICTs that foster PLCs in caring ways (involving facilitating reciprocal relationships, centring collective benefit, being sensitive to needs, using language that is respectful and showing tolerance for diversity and difference, among others). Similar to the principles of *ubuntu*, a religious perspective on the ethic of care includes something as simple as smiling as an act of charity (think of online emojis), welcoming and validating everyone's ideas and checking in regularly (Microsoft Teams or Zoom) to show care for the collective.

From a perspective of care as holistic development, the effort (dedication in an Archerian sense) involves sound, pedagogical use of technological or communication tools and types of activities that go further than sharing superficial information to ones that involve cognitive and reflective engagement (journal tool or e-portfolio tool) in the approaches and practices of the PLC and beyond.

Constraints

Importantly, tools and mechanisms simultaneously enable and constrain the formation of and participation in PLCs. For example, discussion forums are very time-consuming to assess and respond to. Another example is that privacy issues associated with social media tools (Facebook, Twitter, WhatsApp, Instagram, TikTok) have ethical implications, warranting critical thought and careful implementation.

Practical examples

Important to note is that firstly, tool usage must be guided by the underpinning pedagogical principle, and secondly, multiple media are encouraged but in moderation, as it can be overwhelming for members. To see a few practical examples of how ICT integration could foster PLCs in terms of Wenger's (2011:29) value creation criteria, refer to Table 2.1.

With the increasing workload of staff, corporatisation and massification of higher education, staff and students alike find it difficult to maintain

TABLE 2.1: Practical examples of information communication technology integration to foster professional learning communities.

Immediate value: Value of activities and interactions	Potential value: Knowledge capital whose value lies in its potential to be realised later	Applied value: Adapting and applying 'knowledge capital'
Level of participation: Collaborative engagement in a research topic of interest (Google Drive)	Skills acquisition: Asking PLC members to teach and video record a lesson. Others to critique and offer advice.	Implementation of advice: Use scenarios and opportunities to engage in discussion (chat tool, discussion forums)
Quality interaction: Seeing learning as relational and dialogic and intentionally designing a course via an LMS	Inspiration: Share regular updates of achievements, commendations and successes (announcement tool, WhatsApp)	Innovation in practice: Sharing of trends, current research, etc. (Microsoft OneNote)
Level of engagement: Carefully planning and mapping interactions that are within notional hours so as not to overwhelm – online mapping tools or Microsoft Excel	Social connections require both head and heart: Interrogate what PLC members value and what motivates them – through regular check-ins. Recognise and lighten the stress of structural issues (Microsoft Teams, online chat function)	Reuse products: Sharing of resources via Google Drive.
Having fun: Design-based gaming – or have ice breakers via Padlet or Jamboard	Tools and documents: Share via Google Docs or Google Drive	Use of social connections: Use Twitter to connect to experts in the field or industry
Level of reflection: Use a journal tool and reflective questions	New views of learning: Invite others to showcase via online webinars	New learning and teaching approaches: Have take-home assessments such as e-portfolios

Key: LMS, learning management system; PLC, professional learning community.

engagement and PLC momentum. This is in line with Wenger's finding that CoPs need to be actively sustained, and a rhythm needs to be established (Wenger 1998, 2009), taking into account who the participants are. Oftentimes, teachers do not have the technological expertise, skills and experience to integrate ICT into their practice (Naidoo & Vithal 2014), which poses a problem for ITE and higher education in general.

To conclude this section, I want to emphasise that underestimating the value of social presence and compromising on the quality of the interaction is what renders some of the TPD efforts fruitless and mechanistic. Likewise, a focus solely on equipping individuals with effective tools or technological skills would devalue both PLC formation and ITE.

Discussion: Role of ITE – challenging ourselves to do better

As shown in this chapter, in-service teachers and ITE are in dire need of contextually relevant, continuous TPD and hence a need to challenge ourselves to do better. This prompts the question: what can ITE programmes do to better prepare preservice teachers for the complex school sites and the embedded communities they will be entering upon graduation? A related question is: how might ICT integration foster PLCs (collective or distributed agency) to better prepare preservice teachers for their various roles? Initial teacher education programmes and education schools could do better. I propose SR as an analytical lens to frame a few suggested considerations.

Structure

A deliberate critical exploration of education department white papers, school policies, teacher union mandates and other regulatory bodies (the what, how, and why) is suggested so that preservice teachers understand the relationship between policy and practice in collective or PLC mode. This is especially important precisely because policy often does not translate into practice. Hence, making connections explicit to help teachers navigate complex, real-world settings better can be facilitated through ICTs. The policy versus practice divide is something that we know exists and that has been with us for a long time. Identifying the problem is not enough. Considered approaches and practices to mitigate the challenges should be enacted in contextually relevant ways.

In Jansen's (2020:179) study of 600 stories from primary and high school children in South Africa, he suggests 'urgent investments in teacher capability and technological capacity that leads to highly interactive, substantive and resource-rich pedagogies' as a policy implication. Learning design does take time, however, and with decreased budgets, less time for TPD, extended work hours, workload policies, revised learning and teaching plans, ICT policies and strategies become critical. Again, identifying the aims is not enough, but addressing the systemic issues head-on is what is needed. This takes time, energy and resources. as well as bold new approaches and practices.

PLCs could have input (using technological tools such as Google docs) in such policy formation. What is urgent is that we are clear about whether we are aiming for 'elastication' (small shifts) or 'limited expansion' (big shifts) (Archer 2003:148). Additionally, the possibility of 'elastication' seems more probable with collective agency (PLC) than individual effort. In addition, a binary approach is not useful; that is, it is not one or the other but probably a combination of the two.

Culture

The learning, teaching and research culture at each individual institution is diverse and unique in terms of the values, beliefs and practices held dear. Deeply personalised feedback through a culture of online coaching could serve as an enabling mechanism to transform current ones and enable PLCs to share cultural practices (Lave & Wenger 1991). Further enablement includes embracing an open approach that allows flexibility to be enacted and teacher development programme offerings to be updated according to student or preservice teachers' needs (Bali & Caines 2018). The cultural work proposed by Stensaker (2018) could include a vision of ICT integration that promotes:

- Freire (1994) and Morris and Stommel's (2018) critical pedagogies (reflection on real-world problems, questioning or dissent, collaboration or mutual benefit and an attitude of 'what you bring to the table matters'). To clarify, being critical does not imply disrespect. In fact, respect is at the centre of all interactions and tolerance and acceptance of diversity of thought are foregrounded.
- Team approaches and participation in diverse initiatives like CoPs or PLCs and PLNs – learning is complex and requires multiple perspectives, nuanced insights and innovation. Encouraging peripheral participation by novices to full participation by 'old timers' (eds. Hughes et al. 2007) is preferred. Expecting all to participate equally is not only unrealistic, but it is also an unfair expectation.
- Exploring teaching philosophies: 'Each teaching philosophy statement reflects not only personal beliefs about teaching and learning, but also disciplinary cultures, institutional structures and cultures, and stakeholder expectations as well' (Schönwetter et al. 2002:83).
- Changing the culture of 'ICT training' – shifting from waiting to be trained towards immersing oneself in a PLC. This implies shifting to a learning mindset where learning is not confined to a physical space or place, but opportunities for learning exist in conversation with others (dialogic learning), and learning is relational.

- Another shift relates to the nature of support, that is, from technicist, individualistic support to that of supporting collectives, partnerships and alliances. In this way, we all take responsibility for working together, acting together if and when the need arises and leaving no one behind.

The cultural work proposed could start with the intended outcome and then move to the tool – what needs to be mediated – through the tool usage. Another key consideration could be how collective agency can be harnessed to do good (for the PLC and beyond, or the wider community) and which ICTs could aid this work?

Agency

As Lave and Wenger (1991) posit, learning is a process of identity formation and change. This is no different for preservice teachers. Initial teacher education programmes have no choice but to inculcate habits of reflexivity and agency, in the sense that Archer (1995) and Wenger (1998, 2009) and others intended it. Initial teacher education must engage teachers in their own pedagogies in critical ways through PLCs enabled by ICTs.

Through agentic behaviours, values and attitudes, teachers navigate the inhibiting structures and alienating cultures that they are confronted with in the workplace. A word of caution is to be aware of power differentials, as per the critique levelled at PLCs for ignoring them (Smith [2003] 2009). Infuse the use of ICTs that encourage all to participate in making their voices heard (e.g. anonymous input via Padlet). The implication is that agency creates student ownership of TPD, where teachers can engage in PLNs beyond the formal institutional structures (Bali & Caines 2018). What teachers sometimes need are the tools to exercise their agency, and this is where ITE and ICT-mediated PLCs can add value. Providing contemplative tools (such as online learning journals, engaging in social or self-awareness assignments, auto-ethnographies and collaborative reading (Hypothes.is tools, etc.) could help to transform thinking or, as Hayles (2017:12) argues, a radical rethinking of cognition. As an alternative, I want to suggest a shift towards cognitive embodiment – as theorised from an African or Islamic perspective – coupled with embracing, enhancing and supporting the value of the affective turn (the experiences and habits of mind and heart).

Related issues of power, privilege and social justice, reframing narratives and foregrounding teacher voices emphasises the need to do the inner work of hidden actions and intentions of others. We do indeed have the agency to do so. As Boughey and McKenna (2021) argue:

> We have agency, and with agency comes a responsibility to question our common-sense understandings and, indeed, some of the academic literature on student learning. We need to challenge the ways in which theories are misappropriated to focus yet again on the learner's skills or deficits. We need to be alert to how such

> appropriations allow the academic department, the disciplinary knowledge, and the institution to be absented. We have to insert awareness of the extent to which our universities and institutional practices are deeply ideological and historical in nature and serve some students better than others. (p. 60)

We must ask questions about what we hold dear or what we value and reimagine learning theories (for example, cognition is now also visible in the technologies we use). That is, cognition is not limited to human beings and the human brain only, and embodied cognition could now be reimagined from Islamic or African thought, not only from Western conceptions. One example from the Islamic or African episteme on how ICT integration could guide PLC formation in ITE is through viewing TPD as holistic development (not using tools in isolation but rather encouraging ethical use of tools that promote social and spiritual well-being for the good of all).

Conclusion

The South African context warrants a move beyond effectiveness and efficiency considerations, and a focus on ICT skillsets must include the need to centre social justice ideals, transformation and redress. That said, university teachers are part of much of the same struggles that communities face, and thus they also need care. This chapter proposed the building and establishment of supportive PLCs in ITE through ICT integration. Additionally, the chapter called for digital, critical and open or flexible pedagogies for ICT integration, underscored by care beyond managerial approaches, to support PLC formation. The contention is that for PLC formation to happen, we must acknowledge the power differentials inherent in PLCs; interrupt our own minds, policies, practices and cultures; and rethink our life worlds. As the Indian author and political activist Arundhati Roy (2020) asks us to do, ‘let’s imagine the world anew and fight for it’.

Chapter 3

The praxis of critical digital pedagogic practices in initial teacher education

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Abstract

The purpose of this study was to investigate the praxis of critical digital pedagogic (CDP) practices in initial teacher education (ITE). The research problem that I investigated focused on ITE educators being impeded when modelling critical and emancipatory practice while integrating educational technology (edtech) in online learning and teaching (L&T) practices. Educators possessed insufficient knowledge and skills required to create collaborative, interactive and student-centred learning environments. The basic design of the study drew on data collected through the initial phase of an empirical study at the Wits School of Education (WSoE) involving the use of the UNESCO ICT Competency Framework for Teachers (CFT) as a survey and semistructured interviews. The results of the analysis indicated that most of the educators had a partial understanding of critical pedagogy (CP), even though some ITE educators attempted to engage in a certain aspect of CP,

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like mediating for co-creation of knowledge and acknowledging that technology offered a means to student-centred teaching instead of merely transmitting knowledge to students. Initial teacher-education educators' digital skills were at a basic digital competency level. The data indicated that there was an institution-wide limitation around training, technical support, infrastructure and time. This affected the comprehension, understanding and implementation of ICT policies and standards and how ITE educators integrated these into overarching educational environments. Without embedding the basics in place, institutions cannot expect more than standard classroom skillsets with an intermediate understanding on online L&T practices. The focus should not only be on the educators' need but also on the facilitation of effective learning environments for students. In this way, an environment would be created that motivated CPL for academics as a collective and augmented innovation for critical consciousness.

Introduction

Critical pedagogy is based on a philosophy of social movement and education that stems from critical theory. It was promoted by Brazilian philosopher and teacher Paulo Freire (1972), who focused on anti-authoritarian approaches that explored issues of relational power for workers and students. The philosophy has since been propagated by pedagogues and viewed as (Giroux 2010):

> [*A*] praxis-oriented educational movement guided by morals to assist individuals to develop consciousness of freedom, identify authoritarian trends and connect knowledge to power, through constructive action. (p. 15)

Engaging in a CP was a way to consider practices and perspectives as ITE educators, especially as they struggled to synthesise culture with L&T and edtech (Johnson et al. 2016). Employing the use of edtech in L&T required digital competence, which I found technicist (attaining targets through mechanistic means) and conflictive. Through the lens of critical realism (CR) (Bhaskar 1975), I expanded on the tensions between CP and edtech in ITE, as I believe that inasmuch as ITE needed to keep relevant with the use of edtech, it should and must be significant in laying the foundation of being agile and versatile through research-informed continuous professional learning (CPL).

Critical pedagogy was analysed and discussed in the literature review, but for brevity I would like to mention that the nature of CP was such that it invoked the term 'critical' as an educational goal that was valued (considered to be important). A major cornerstone of CP was around knowledge and cultural formations that legitimised an unjust and prejudiced status quo. To undo this, it was crucial that critical capacity be fostered in the populace, enabling them to resist power differentials through their access to the dominant syntax (various forms of knowledge). It was this aspect that

ITE educators needed to be cognisant of, as they were the stakeholders who were educating future teachers.

Digital competence meant possessing skills, knowledge and attitudes that enabled confidence in the use of edtech. I view most digital competence frameworks as technicist, as they made no mention of critical praxis. While CDP was about understanding the creation of technologies and its location around competencies, CP focused on access to various forms of knowledge (Uddin 2019) and for academics to align to a particular digital competency without them having in-depth knowledge of the technology itself. This was the tension that brought about complexity. At the same time, another tension was that there had to be research around CP to inform educator practice, and many educators were focused on teacher-centred practices. Bringing out the tension between CP and digital competence is the contribution that this chapter makes.

The study was within the context of the WSoE at the University of Witwatersrand (Wits), a large public-funded university in South Africa. The case study underwent many transformations and name changes, which is currently positioned as the WSoE. From inception, a feature of studies at the WSoE was the integration of theory and practical teaching experience. This approach was one of the characteristics of ITE at the school.

Research problem, aims and research question

The WSoE, through Wits, is mandated to educate preservice educators for the complex, diverse and innovative classroom that incorporates edtech in practice. Educators at the school had a dual obligation and commitment towards preservice educators, namely, to prepare them for being responsible citizens in a globalised world and to prepare them for 'graduateness' (Department of Higher Education and Training [DHET] 2012, 2014). However, some educators at the WSoE were impeded when modelling critical and emancipatory practice with educational technology, as they were not fully equipped with the knowledge and skills required (Johnson et al. 2016) to create collaborative, interactive and student-centred learning environments.

I believe that the problem was twofold; the first related to the aspect of skills using edtech, and the second (more pervasive, perhaps) was that many lecturers remained unaware of the enactment of CDP and hence did not think critically about how and when edtech was integrated into L&T practices. While considering that CP was the focus of this chapter, it was equally important that pedagogy – one of the six crucial focus areas of the CFT framework – was viewed across the three phases of the framework. This translated to educators being digitally fluent (knowledge deepening) while attempting to transition to the level of mastery (knowledge creation), as opposed to being digitally literate (knowledge acquisition). However, this notion is technicist because technology was viewed as the saviour of and an improvement on society with no mention of critical praxis. Being mindful of the tension between CP and digital competence was the contribution that this chapter made.

This research aimed to determine and examine ITE educators' critical digital pedagogical practice in their teaching. In doing so, the intention was to develop and implement suitable CPL programmes through research-informed practice to support educators. To do so, the research posed the following question: how do educational technologies influence ITE educators at the WSoE in their critical pedagogical practices?

Significance of the study

This study was important because the WSoE was committed to becoming a research-led teacher education institution, and to achieve that, a project that focused on CP and edtech integration was useful. It was anticipated that appropriately having some indication of educators' CDP practices would lead to better L&T across the school and the hope of drawing attention to the importance of social justice and emancipation.

Literature review and theoretical framework

This section explored the theoretical underpinnings regarding digital competency, edtech and the adoption of CP practices of ITE educators through a review of the literature linking them. I expand on the tensions between digital competency as a framework and CP. I develop my argument about the tension and what can be saved from the digital competency framework and adapted for use in a truly critical digital integration. I draw on Freirean CP to discover the resonance and (dis)harmony between the constructs. This drawing involved assumptions underlying the concepts of Freirean thought, notably the critique and the revolutionary character of the concepts of dialogue and conscientisation. Within the Freirean pedagogical practice, the difficult role of the educator as a facilitator, coupled with the mechanics of edtech and the liberating nature of the dominant syntax (the dominant forms of knowledge in capitalist societies), was raised and argued.

The theoretical frame of CR was employed because, in its own right, it was considered a worthy approach to view and address particular complexities in education and society at large. So it is with critical theory, hence CR, in mind that I reflected upon the ways that education might nudge us along in our attempt to focus more on the human aspects when engaging edtech at the real level because education is a social phenomenon and a very important institution in every society or country.

Critical pedagogical practices of initial teacher-education educators

It is crucial for ITE educators to assist their students in developing their capabilities in establishing the classroom environment and preparing the learning opportunities that facilitate students' use of technology to learn and communicate. The pervasive use of edtech in all areas of life calls for the need for new skills and competencies.

Advocates of CP do not accept that knowledge can be politically neutral and argue that teaching is an ongoing political act, irrespective of whether the teacher acknowledges this or not (Hooks 2003; Kincheloe 2008; McLaren 2016). The aim is emancipation from oppression through the realisation of critical consciousness, thereby encouraging people to make changes and self-actualise through political action and social criticism. This is not to say that CP has not been critiqued. In a similar vein, there have been arguments made that Freirean philosophy is inappropriate for educational institutions to promote radical political activism among students at the expense of teaching them other skills, like writing proficiently, which is one of the aims of ITE.

Shor (1992) viewed CP as:

> Habits of thought, reading, writing, and speaking which go beneath surface meaning, first impressions, official pronouncements, traditional clichés, received wisdom, and mere opinions, to understand the deep meaning, root causes, social context, ideology, and personal circumstances of any action. (p. 129)

Shor's conceptualisation aligned with the radical sociology of the late 1960s and showed commitment to social transformation as a form of 'empowering education' that was agnostic to social emancipation or from capitalist society on the whole. The intention was to attain a 'deep meaning' (Shor 1992:125) of the mechanics experienced in educational institutions like universities and schools.

For me, CP should have its foundations focused on a critique of capitalist society that reproduces value as essential commodities through structures built in them, like money, media and technology, labour and capital. If educators critique these structures, then they are truly engaging at the heart of CP. In this way, students will comprehend the nature of social domination in capitalist societies. Hence, social emancipation, for me, implied liberation from these abstract social structures and dominant syntax (the dominant forms of knowledge in capitalist society). It was imperative that we understood them as crucial components of CP and anticapitalist education.

The link between CP and ICTs amounts to an L&T approach in the online space. This form of teaching commences by examining critical theories with the intention of interrogating online tools, the LMS and digital habits to ensure that a humanising pedagogy of care is enacted (Morris & Stommel 2018).

In doing so, a pedagogical practice that focuses on collaboration and integration occurs as open dialogue and problematising ensue. This stance is one of social justice through education but education and knowledge acquisition in the online modality, which demands some competence to engage in L&T practices.

Digital competence and continuous professional learning of initial teacher-education educators

To facilitate online L&T practices, ITE educators needed to engage in effective CPL apart from augmenting their digital competence. For the continuum from digital literacy to digital mastery, they needed to possess effective and ethical online communication skills, good quality resource creation and curation skills, knowledge co-construction and understanding abilities. This would lead to the comfortable and ethical use of edtech.

To promote digital competence[9] and confidence, equal emphasis had to be allocated to the digital competence development of ITE educators and to infrastructure development. Access to these technologies, especially in L&T, was important, but fluency (deepening) through to mastery (creation) of such technologies was equally important. There should be a wide range of digital tools for educational use. In creating a shared vision of digital competencies (pedagogical, best practices and implementation), an institution was required to not only empower educators with an understanding of how the functionality of the different tools operated but also why and when it was useful, as this contributed to critical pedagogic practice because the tools used were fit for purpose.

Digital fluency was assumed to be another name for digital literacy. However, research demonstrated that digital fluency was the next level of capability to digital literacy (Briggs & Makice 2012). Seemingly, digital mastery was the ultimate level that one could attain. Much of what applied to digital literacy was also true of digital fluency, where there was a need to be digitally literate to be capable of digital fluency, but fluency related to a cognitive ability to understand the underpinnings of what was being done, why it was being done, if and when it should be done and how to do it to successfully achieve L&T goals (Briggs & Makice 2012). Holland (2013) suggested that

9. Levels of digital competence are generally viewed as a continuum and aligned to the *UNESCO ICT Framework for Educators*, whereby digital literacy (that equates to knowledge acquisition) refers to a basic understanding of how to use educational technology tools; digital fluency goes a step further (and equates to knowledge deepening) where the ability is to move vertically with knowledge and new content with these tools. Digital mastery (which equates to knowledge creation) is the ability to create new learning and teaching interactions, which reflect the interconnectedness of content areas and make use of a variety of strategies and assessment tools to design and develop learning experiences to reach all students. The mastery level is second nature to the individual.

being able to make inferences was a key point of being digitally fluent, and this was important because of the speed and pace of the changing technology; there was a constant need to explore and expand capabilities. I argue that Holland (2013) was absolutely uncritical about who was driving this speed and pace and why, as it was usually market-driven and focused on profit generation. Above all, this had implications for critical pedagogies as it affected how technologies were viewed and used in the context of ITE because students would critique the needs of those who were pushing the speed and pace at which technology was taking over daily activities.

Viewing the problem through the lens of critical theory and critical realism

Critical theory and critical realism (CR) were commonly associated because of the emancipatory intentions present in both, sharing the same foundation. Critical theory grew out of The Frankfurt School in Germany in the 1930s and became more internationally recognised in the 1960s. The commonality between critical theory and CR is their overlapping nature of sharing common Marxist origins concerned with unveiling the 'real state of affairs' in society. The key argument of critical theory was that 'all knowledge, even the most scientific or "commonsensical", was historical and broadly political in nature' (Friesen 2008:1). Critical theorists argued that knowledge was shaped by human interests of different kinds, rather than standing 'objectively independent from these interests' (Friesen 2008:3). Critical theory focused on critiquing knowledge that presented itself as 'certain, final, and beyond human interests or motivations' (Friesen 2008:2), and its central purpose was to destabilise such knowledge. Critical theory, in sum, sought to 'make problematic what is taken for granted in culture, and it did so in the interests of social justice, especially in the interest of those who are oppressed' (Allen-Brown & Nichols 2004:5).

Critical realism stemmed from Bhaskar (1975), who conceptualised it as a philosophy of knowledge and being. When employed in studying the world, it used the logic of 'retroduction', which involved working back inferentially from a known regularity to identify a completely unknown or suspected explanatory mechanism. For critical realists, ontological depth was a crucial consideration, and they argued that reality was stratified according to three domains: the empirical, the actual and the real. The empirical referred to the level of experiences and observations, while the actual referred to the level at which events occurred, and both these levels were impacted by the real, occupied by generative mechanisms. Generative mechanisms were the primary focus of CR research, although they were empowered to cause events and not directly observable. Consequently, I believed that CR, in taking a position within the ontological, epistemological and aetiological paradigms, was a means to ameliorate some tensions in CP and educational technology. I used a realist approach in my endeavour to realise the intangible in my understanding of edtech-influenced ITE educators and their CDP practices.

Methodology

A qualitative paradigm was employed within a single case study methodology that examined and explained crucial constructs within the context of the WSoE and ITE. The primary research instruments comprised semistructured interviews and a survey. The survey was based on the UNESCO ICT-CFT. Google forms served the study well in administering the survey to attain a baseline assessment of the digital competencies of the educators at the WSoE. However, for the interviews, I engaged in purposive sampling as the aim was to invite those educators at the WSoE who engaged quite deeply with edtech within the context of ITE.

Semistructured interviews allowed for in-depth information to be gathered from research participants on their thoughts and opinions on critical digital practice. The initial response was at a surface level, meaning that I had to use follow-up questions to obtain a deeper (in keeping with the critical realist lens of this research) and complete understanding of the participant's meaning. The in-depth format also allowed me to explore factors that underpinned the participants' responses, namely, reasons, opinions and beliefs. This ultimately provided explanatory evidence, which is a critical element of qualitative research. In summary, the researcher, as an instrument of research, enacted the tenets of CR through viewing the data for deeper meaning at the level of the real.

Once the data were collected, I was able to determine the interventions that were necessary for each of the three ICT-CFT levels (knowledge acquisition, knowledge deepening and knowledge creation). The intention was to use the data to identify and develop CPL programmes tailored to the lecturer's needs based on the following focus areas of the educators' professional practice: *understanding ICT in education policy, curriculum and assessment*; *[critical] pedagogy*; *application of digital skills*; *organisation and administration*; *teacher professional learning*; and *[research]*. Of equal importance was the need to highlight that this framework was adapted to reflect the aims and values of CP by the teacher in the ITE programme. Hence, the inclusion of the concept *critical* as aligned to pedagogy and the focus of *research* because of research-informed practice for improved L&T. As a practice-based research approach was used, CPL programmes included this component to empower ITE educators on how best to conduct such an investigation.

It was critical that any research study avoided bias in the interpretation of its results as these could influence the integrity of the study (Lincoln & Guba 1985;

Merriam & Tisdell 2015). The constructs of reliability and validity were not treated as separate in a qualitative paradigm. They were often associated with similar terminologies such as transferability, credibility and trustworthiness. In this study, participants were engaged in a respondent validation process whereby transcribed data were scrutinised by participants to check that appropriate interpretations and valid conclusions were drawn.

The necessary ethical requirements were obtained as per protocol number H19/11/19 from the university, as well as from the WSoE head-of-school (HoS), by providing a thick description, in writing, of the envisaged purpose and scope of the study. An email from the HoS sufficed to use the school as a research site. Sensitisation sessions were held with participants who were provided with a clear explanation of the proposed research. Concomitantly, informed consent was obtained from all participants who were invited to participate voluntarily in the study through a verbal briefing, followed by an email for acknowledgement. It was a common understanding that pseudonyms would be used to protect participants' identities in the course and write-up of the research.

Data analysis

The study engaged in thematic analysis by identifying experiences (at the empirical and actual level), analysing thoughts (at the real level) and reporting behaviours as patterns or meanings from the data set in the survey and interviews. Subsequently, the codes that emerged were packaged into more organisational schemes that related to the focus areas of the adapted UNESCO ICT framework and reported thereof:

- understanding ICT in education policy
- curriculum and assessment
- CP
- application of digital skills
- organisation and administration
- teacher professional learning
- research.

A critical realist approach (the empirical, the actual and the real levels) was then employed in the analysis to seek the deeper meaning of what the participants were actually stating, according to their worldview. Of importance was that this chapter focused more on the interviews as the main data source and drew on the questionnaire data as enrichment, where relevant.

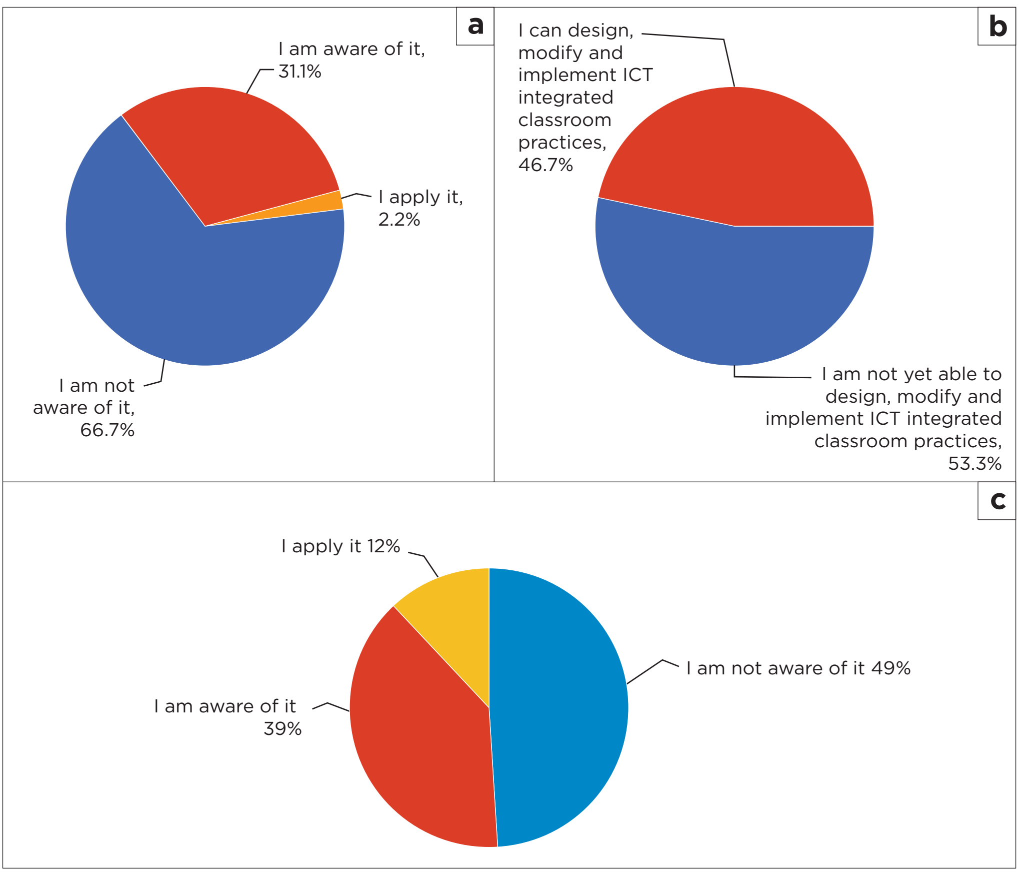
Discussion with visualisations

At the empirical level, 49 ITE educators participated in this study, comprising 63.0% female and 34.8% male. Most participants were highly qualified educators, with 79.5% holding PhDs and 20.5% possessing a master's (MA) degree. They possessed a basic understanding of digital skills with standard classroom skillsets and an intermediate understanding of flipped classroom practices. Most of their CPL courses were completed through the CLTD and Wits. The data were analysed through three levels (empirical, actual and real) and discussed beneath the seven themes of the educators' professional practice.

Understanding information and communication technology in education policy

According to Figure 3.2, UNESCO ICT-CFT did not overtly mention critical pedagogic practice but rather alluded to a pedagogy that facilitated.

In the context of the Wits digital policy and national ICT policy (as in Figure 3.1), even though educators focused on the idea of student-centredness



Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.1: Understanding and application of ICT educational policies: (a) national ICT policy, (b) policy application and (c) university ICT policy.

Building workforces which have ICT skills to handle information and are reflective, creative and adept at problem-solving in order to generate knowledge
Enabling citizens to be knowledgeable and resourceful so they are able to manage their own lives effectively, and are able to lead full and satisfying lives
Encouraging all citizens to participate fully in society and influence the decisions which affect their lives

Source: UNESCO (2011).
Key: UNESCO, United Nations Educational, Scientific and Cultural Organization; ICT, information and communication technology; CFT, Competency Framework for Teachers.
FIGURE 3.2: UNESCO ICT-CFT.

and critical aptitude, most of them remained unaware of it, let alone engaging with its promotion of CP. Figure 3.1 also depicts how, in all, 46% of the participants remained unaware of the ICT policy and 32% were aware but did not apply it, while 12% of the participants applied the policy in L&T practices. This aligned with a basic application of digital skills. Perhaps this was a result of the institution not sensitising educators around the policy correctly. The interviews revealed that when educators requested advice on policies, management pointed them toward the Wits Intranet to view it rather than sensitising them further. There was insufficient training and sensitisation around the policy as it was not withered down to the lower levels in the institution.

Participant 7 (P7), a 59-year-old female academic, worked at Wits as a L&T specialist for over 25 years. She stated that she was aware of the policy, but it did not have a big influence on L&T practices. She had subsequently been involved in collaborative research projects on L&T in education studies but has not engaged in formal ICT training. She stated:

> 'I was actually resistant to it as I was worried that things will be imposed without real understanding as it was forced in a way as we had some agency. Some of the policies are out of sync with who our students [*education students*] are. I feel strongly about access to education as we must know how to do it properly. Selection, sequencing and pacing are important.' (P7, 59-year-old female academic, worked at Wits as a L&T specialist for over 25 years)

Participant 7 appeared to be resisting the technicist assumption that technology was always good and should always be used if it was available without mention of critical pedagogic practices. She omitted the notion of critical pedagogic practice or alluded that it was a part of integrating edtech with pedagogy. She appeared unsure about the interplay of policy in L&T practices; therefore, she took the middle path of comfort with what she already knew. This related to the theory around a deeper meaning of the structure and culture of the university and how academics were sensitised or desensitised to new structures as policies were structures intended to enable L&T practices (49% of participants remain unaware of digital policies). As institutional structures, a lack of awareness of digital policies precipitated the digital exclusion of participants, which influenced how they integrated edtech into CDP practices.

Curriculum and assessment

Initial teacher-education educators possessed increased proficiency in curriculum and assessment (47.2%, as depicted in Figure 3.3), as most of them were closer to being experts in this area. However, Figure 3.4 depicts that their proficiency in integrating technology with pedagogy remained insufficient, as they engaged in ICT-enhanced teaching (72%). This focused on the LMS (Wits-e) as they integrated pedagogy within curriculum and assessment, but they were limited in facilitating complex problem-solving (14.6%) and engaging in self-management with respect to their pedagogy:

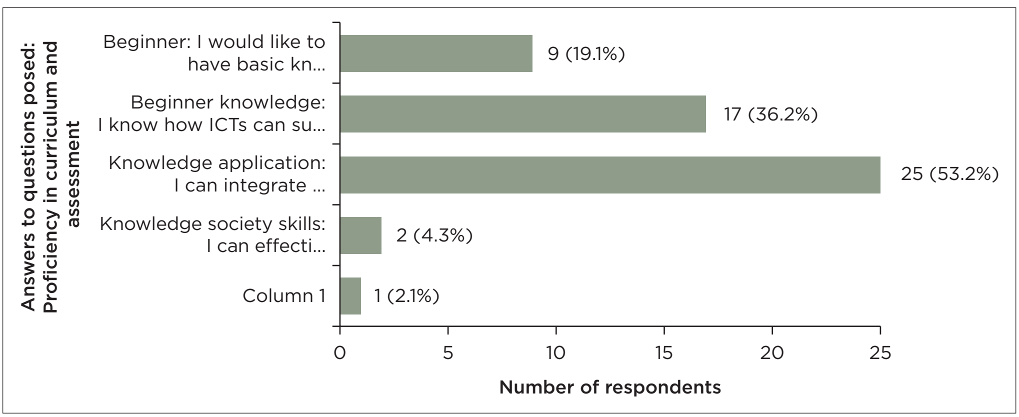
> 'Technology needs to be related to our culture at this school. […] we are so used to face-to-face (f2f) teaching, and the challenge comes in now with this new norm.' (P6, age unspecified, occupation unspecified)

> 'Here we have to fight for resources and grow an enabling culture to include technology in the ways of doing and being.' (P9, age unspecified, occupation unspecified)

It appeared that a common struggle was the disenabling culture of integrating edtech into the curriculum because of limited understanding and knowledge of integration.

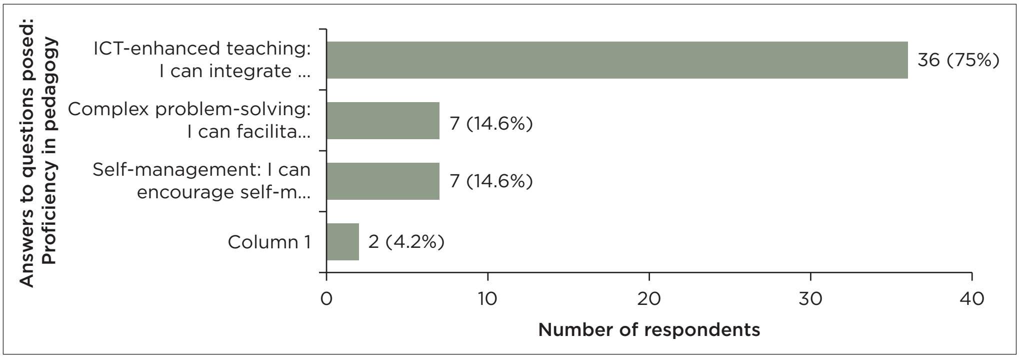
Critical pedagogy

Most participants had a partial understanding of CP practices. Moreover, the notion of CP was omitted in the UNESCO competency framework to include the term 'pedagogy'. Figure 3.3 and Figure 3.4 indicated that even though participants integrated ICTs in their teaching, it was perhaps in a manner that translated to content delivery, as the interviews stated otherwise:



Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.3: Curriculum and assessment skills.



Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.4: Pedagogical practices using educational technology.

> '[*A*]t a higher level, this relates to management foresight, because a policy that encouraged and displayed implementation of blended L&T would have assisted us in aspects that can be changed and made to change [...] my view is that our mindsets would have been used to transitioning and thinking about CP in the online space.' (P6, age unspecified, occupation unspecified)

> '[*A*] teaching approach that promotes critical engagement with subject matter and accepts views from students that challenge the way things "have been done" by so doing opening spaces for innovative ways of dealing with ideas.' (P9, age unspecified, occupation unspecified)

> '[*N*]o, it's not my area but I thinks its related to paying close attention to day-to-day and what the realities of students are [...] includes understanding the work that they do, experience and work with others and create knowledge.' (P8, age unspecified, occupation unspecified)

Participant 6 was of the view that the policy and strategy documents were not inclusive of critical pedagogies and needed to be reviewed and communicated sufficiently. Participants 8 and 9 possessed a close-linked view to critical pedagogies in the f2f and not blended modality. It appeared that participants viewed pedagogy, critical pedagogies and edtech in silos. If they consolidated the three concepts into critical digital pedagogies and socialised their ways of doing, being and becoming, then their practice would be suitably augmented in a specific manner. Instead, the notion is that the policy is lacking hence their lack of knowledge. But what about their exercise of agency and self-efficacy?

When asked about how educational technology was infused in their L&T, educators' responses were partially encased in critical pedagogic enactment:

> 'I allow the students to solve problems using ICT in the classroom. I also allow them to use ICT in their teaching simulations as preservice teachers, even when doing their presentations in class. I also think that we can have fewer contact sessions so that students will be compelled to use a variety of ICTs that are at their disposal.' (P8, age unspecified, occupation unspecified)

> '[*T*]echnology is now with us, and we cannot avoid it, and we can take advantage of the existing technology at the WSoE, which is insufficient, and we force students to think critically and see something that they could not see when using the traditional methods of teaching. Technology uncovers the hidden aspects. Now they learn to collaborate and become co-creators of knowledge with us.' (P7, 59-year-old female academic, worked at Wits as a L&T specialist for over 25 years)

From the statements by Participants 7 and 8, it is evident that some ITE educators try to engage in a certain aspect of CP, like mediating for the co-creation of knowledge and acknowledging that technology has also offered a means to student-centred teaching instead of merely transmitting knowledge to students.

Technology has transformed education, meaning that the previous f2f contact is diminished. Now because of technology, the teaching is student-centred; one must ensure that the student understands, and the easiest way of seeing this is by putting them in groups to collaborate. Freire says that the kind of teaching we used to do:

> '[*L*]ike transmitting knowledge to students has to stop. Now with ICT and technology, that teaching is fading away, and he refers to it as a corpse and dead knowledge. I like how he says that we must run away from that teaching and allow for collaboration. We learn from our students.' (P5, age unspecified, occupation unspecified)

Participant 5 has alluded to a sound understanding of CP but did not consider how to enact it using ICTs. 'Technology uncovers the hidden aspects' translates to technology highlighting or making visual the collaborative practices and hidden aspects of critical thinking between students that were not visible in traditional lectures. Integrating edtech did not lead to student-centred L&T practices. This highlighted an insufficient understanding of the enactment of CDP practices.

Four participants were of the view that authentic tutorials and activities for the online space needed to be considered. They believed that when they facilitated tutorials, students habituated the concepts in the curriculum and failed to explore their experiences in the online space within specific contexts. This mattered a great deal, as educators were of the view that if students were able to make meaning out of the knowledge they attained, they would find the relevance of their learning in their lives. Many educators confirmed that they used Wits-e as a repository to upload content for students. Two educators were adamant that they preferred f2f teaching:

> '[*W*]hen I do f2f, I interact with students directly, see their facial expressions and hear them whisper and develop my pedagogy from what I see and hear. I don't like using technology to teach.' (P6, age unspecified, occupation unspecified)

Participant 6's response related to the focus of this chapter, as the purpose was to investigate the praxis of CDP practices in ITE, and it appeared that some educators were reluctant to adapt to new ways of being and becoming.

The notion of what the CDP as enacted focused on seemed limited in educator perceptions of what it would look like and how to achieve it through CPL. Participant 7 had some idea of CDP enactment. Initially, he could not conceptualise a CP that infused technology as a collective. When I probed him further, he constantly went back to isolating CP and edtech. I argue that it is this isolation that exacerbates the research problem by the limited skills and confidence in the use of edtech, and literature supports this in the area of self-efficacy:

> 'I think we have to think more about authentic tuts [*tutorials*] and activities. When we give them tuts [*tutorials*], do they learn the concepts in the curriculum or do the tasks enable them to explore their experiences in the online space in a specific context that are not the same? This matters, as this enables students to make meaning out of the knowledge they are attaining. I have to find the relevance of their learning in their lives. If it's abstract and bookish, it does not help them. I have to ensure that the knowledge is relevant to them and their lives and living contexts. A student in Soweto and the student in Sandton must be able to make meaning of the same knowledge, even if they are in different contexts.' (P7, 59-year-old female academic, worked at Wits as a L&T specialist for over 25 years)

This view of CDP ran in a similar vein in all the interviews. Most participants viewed the use of edtech as separate from their pedagogy. Even though participant perceptions of what a CDP would look like appeared limited, their notions of how to achieve it through CPL appeared promising. This pointed to the need to recognise CP as a force behind the transition from f2f to online L&T, as substantiated in some of their comments:

> 'I think we must do a lot with educating one another, as people with knowledge in that space need to educate others on how to use technology in the classroom and to enhance learning in way that is student-centred.' (P5, age unspecified, occupation unspecified)

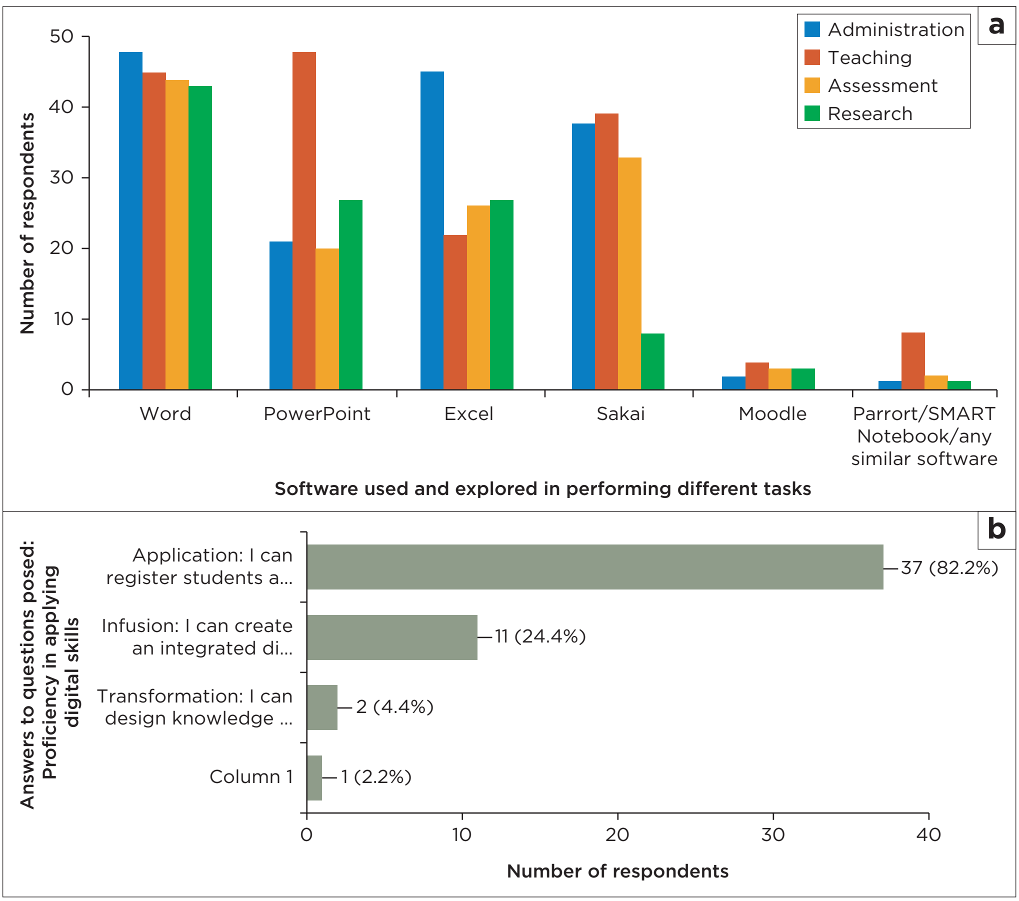
> '[*O*]ne thing with a CPL community, as a community of practice, is the collaboration and getting together and looking at our practice. How are we doing things, as we all don't all do it similarly? There are some of us that are ahead in using technology. The CPL community supports one another.' (P8, age unspecified, occupation unspecified)

> 'It can help by continuous professional learning for educators. The hindrance is when we sit with the knowledge, and we do not share it in communities. I was complaining that I'm not getting enough help on Wits-e and then I attended the FOI course at the CLTD, and I learn more about how to teach in the online space.' (P4, age unspecified, occupation unspecified)

Participant 4 demonstrated that self-efficacy was the generative mechanism that was intrinsic to every educator. Even though structures existed to enhance competencies and L&T practices, they depended on the exercise of academic agency. Collectively, it appeared that pedagogy came before technology at the WSoE. Educators focused on attempting to help students understand what the prevailing pedagogies were and how they questioned those prevailing pedagogies. At the same time, they questioned how they themselves, who were employed by the state (faced with a hand-me-down curriculum), negotiated these curricula in ways that allowed them to meet the requirements of the institution while considering more open-ended approaches to knowledge construction. Was this, in part, because of their focus on f2f L&T practices?

Application of digital skills

According to Figure 3.5, more than 90% of educators used a laptop, desktop or personal computer for administration, teaching, assessments and research; less than 20% were utilising tablets, smartphones and smart boards; 82.2% had a basic understanding and implementation of digital skills, while 24.4% were at the intermediate level; and 75.0% could organise and support learning



Source: Figure developed through Google Survey on 20 August 2020.
Note: Data and clarification thereof available from the author, upon request.

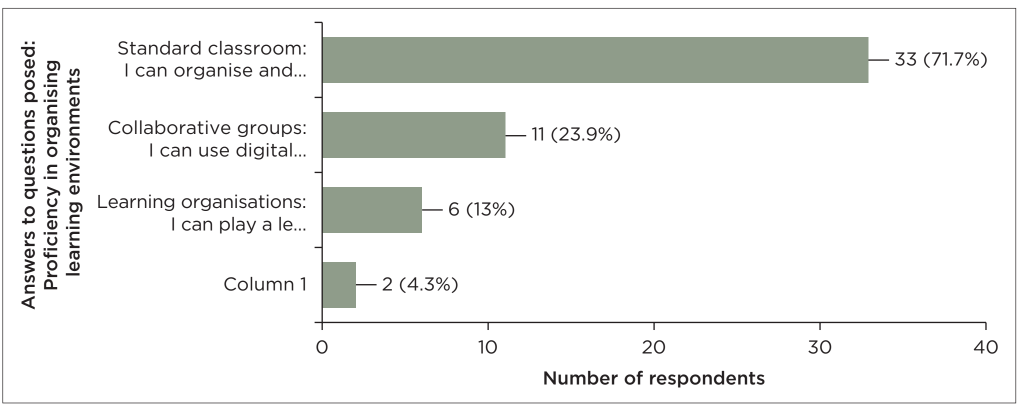
FIGURE 3.5: Digital applicable skills: (a) explored software and (b) proficiency in digital skills.

environments in an inclusive manner, while 47.9% could use digital tools flexibly to facilitate collaborative learning and administer the learning process. Initial teacher-education educators were functioning at a basic digital competency, but their qualifications remained at the highest level that one can attain as an educator. They were quite senior, as most of them were between 46 and 55 years, and they had been long enough at Wits to understand the CPL processes to enable them to socialise themselves into augmenting their digital competencies. Perhaps this was reflective of both the educators and the institution, as it appeared that educators did not have sufficient time for CPL. It translated to a situation where even though the structures existed, they remained insufficient.

The challenge related to educators' pedagogy, as the data indicated that there was limited infrastructure from ICT and limited CPL to improve their L&T practices. The data also indicated that there was a high educator workload because 57% of educators supervised the master's coursework and the bulk of the work was in the honours programme. If ITE educators did not have the time (because of high workloads) and resources (that are limited) to augment their skills, then they would basically engage in the bare minimum, perhaps because of the existing policies, procedures and institutional environment that required a review.

Organisation and administration

Figure 3.6 demonstrated that educators could register students and upload documents (this was at a minimal level) but that there was minimum movement on transformation (designing knowledge communities). Educators possessed the basic requisites to use the basics of digital tools, but they required assistance in the actual creation of online environments that led to pervasive learning.



Source: Figure developed through Google Survey on 20 August 2020.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.6: Organisational and administrative skills.

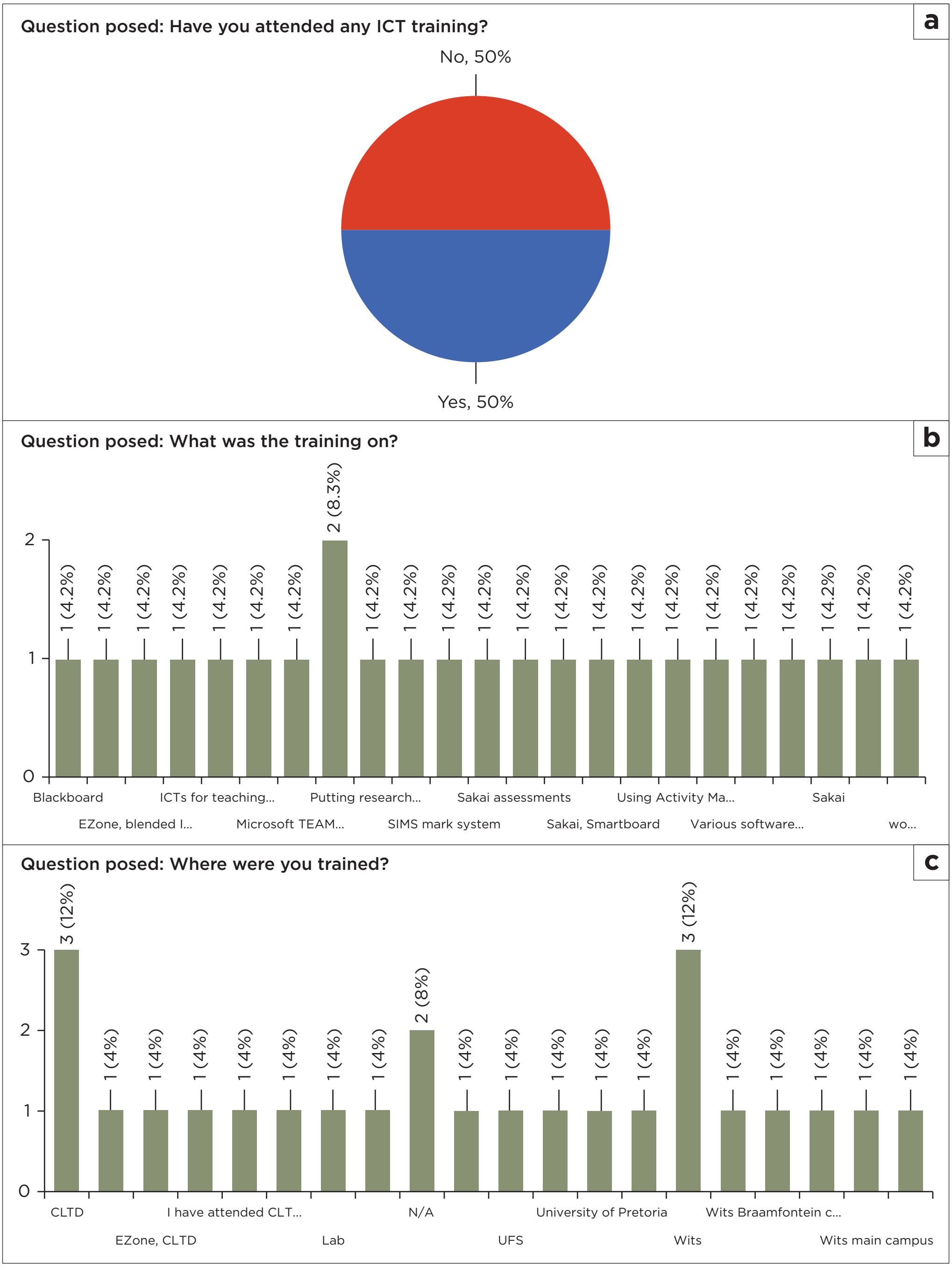
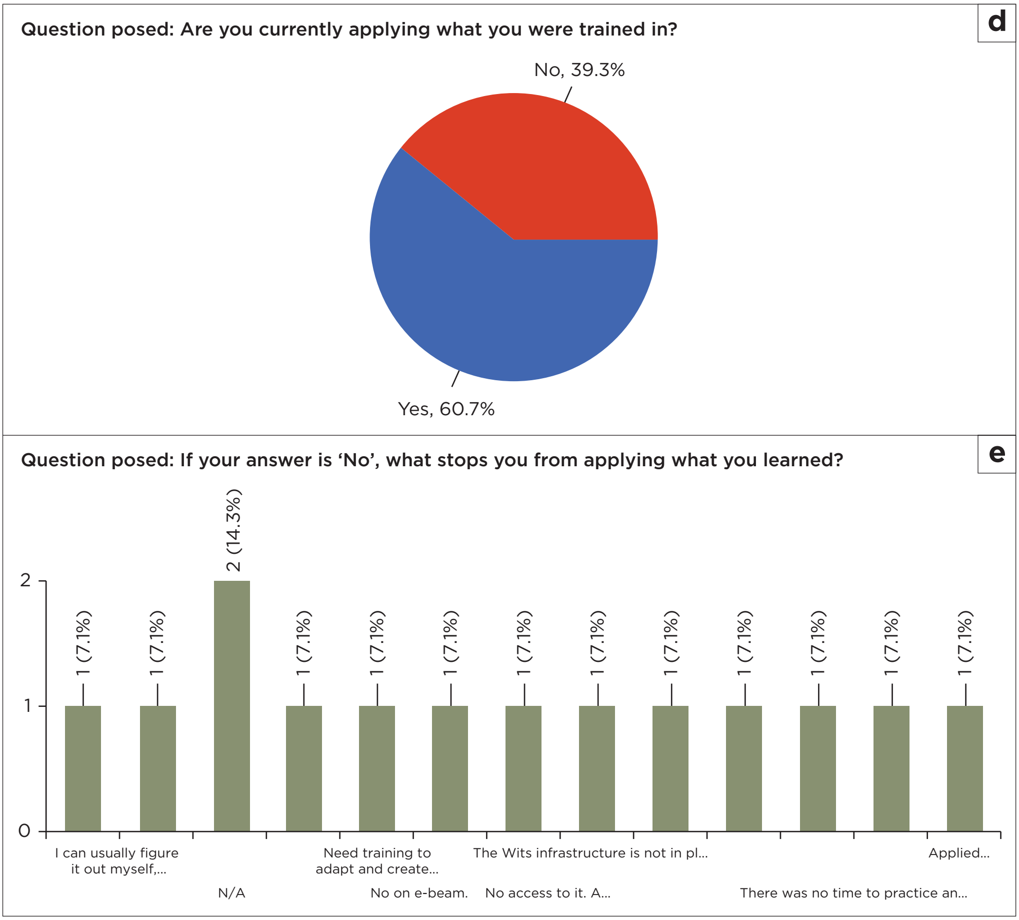


Figure 3.6 continues on the next page →

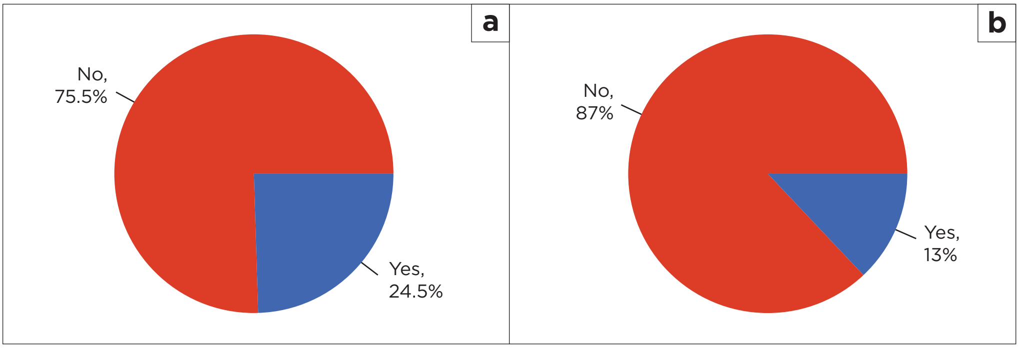


Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.7: Continuous professional learning patterns of educators: (a) Have you attended information and communication technology training? (b) What was the training on? (c) Where were you trained? (d) Are you applying your training? (e) What stops you from applying what you learned?

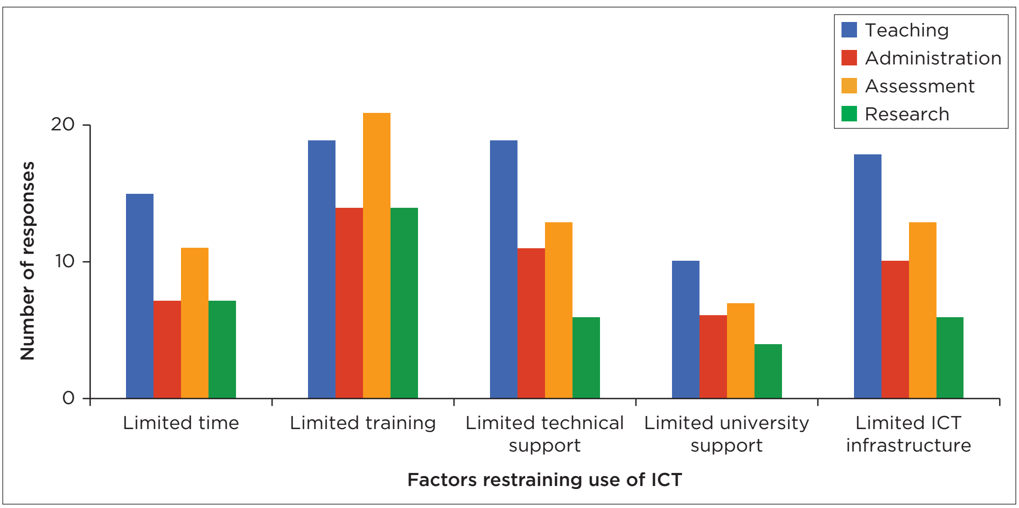
Teacher professional learning

Fifty per cent of educators attended ICT-related courses and CPL courses, mainly from CLTD and Wits. Twelve per cent stated that they engaged in CPL at Wits Braamfontein. Seemingly, the CLTD provided much of their CPL even though the CLTD has engaged mainly in curriculum design and development, which contributed to the data in 19.2 in Figure 3.7 over a period of ten years. I assumed that the postgraduate diploma in Higher Education did not have a strong emphasis on the digital aspects (perhaps only in the last year and a half) because of the institution's limited foresight and implementation of relevant CPL for blended and online environments.



Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.8: Research habits of educators: (a) have you been involved in an ICT in an education project? (b) Do you have or have you supervised a postgraduate ICT research project?



Source: Figure developed through Google Survey on 20 August 2020.
Key: ICT, information and communication technology.
Note: Data and clarification thereof available from the author, upon request.

FIGURE 3.9: Factors that impeded educators' use of information and communication technology.

Research

A total of 93.3% of the ITE educators facilitated the undergraduate (UG) programmes at the WSoE. A total of 73.0% of them facilitated the postgraduate (PG) programmes. As can be gleaned from Figure 3.8, I wondered if it was feasible for educators to engage in L&T practices in both UG and PG programmes, supervise students and also attend CPL. This resulted in a high workload, which educators were not coping with. It pointed to irrationalised expectations from senior management. The sustainability of the institutional or work ethic culture was at risk because of all these demands. If blended L&T practices had been implemented ten years ago, it would be easier for educators to adapt to circumstances, transitioning and change now. Most academic narratives that I have accessed on blended learning globally began in early 2003, while Wits was only implementing L&T using technology (through its policy) around 2015, implying a lack of foresight. Even in research, there was foresight required on the digital knowledge economy. Much emphasis was placed on research (Wits being a research-intensive institution), but it did not focus on L&T with edtech that would have transitioned to CDP practices through the university's focus on the decolonisation project that related to social justice.

Conclusion

The survey and interviews revealed that ITE educators were at different levels in the UNESCO ICT-CFT. The overarching theme emphasised that they were operating at an intermediate or basic level of digital competency. There were different levels within the framework where educators were stronger, such as in curriculum and assessment; however, they were limited at CDP L&T practices and organising digital learning environments.

In summary, Figure 3.9 highlighted the challenges that WSoE educators faced when attempting to attain effective critical digital competencies. With regards to teaching and assessments, there was an institution-wide limitation around training, technical support, infrastructure and time. This affected the successful comprehension, understanding and implementation of ICT policies and standards and how ITE educators integrated these into overarching educational environments.

Without embedding the basics, institutions could not expect more than standard classroom skillsets, with an intermediate understanding of blended learning practices (which the survey highlighted). Institutions need to create closer community cooperation bonds between all stakeholders through effective communication and improved coordination for continued ITE. The focus should be on both the educators' and students' needs in facilitating effective learning environments for students. This would create an environment that motivated CPL as a collective and augmented innovation for critical consciousness. In analysing the criticality about why innovation should be valued for its own sake, this was part of the capitalist ideology of valuing newness for its own sake, creating a new need and a new market to make more money. In the critical tradition, innovation was valuable if it improved human life and achieved greater equality and justice; otherwise, it remained as another form of oppressive power.

There should be a better connection between the pedagogical and practical environment. With regards to the unsatisfactory institutional culture, ITE educators need to be cautious, as this contributed to eroding the best practice of keeping the essence of what a CP using edtech meant, not through the enforcement of capitalistic practices but rather the adoption of the dominant syntax. If not, this affected the well-being of individual societies and environments by not creating equitable, diversified, empowered, self-deterministic, enlightened and responsible preservice educators.

Garnering these observations, a few suggestions for further research can be assumed. There was a gap where further knowledge could be built around the varying levels of an educational system that focused on critical digital pedagogies. Nevertheless, further research should investigate how the theory and practice of CDP could shed light on the various links to ITE, such as institutional infrastructure, online L&T policies and leadership (within the context of a research-intensive university) with foresight. Additionally, edtech integration into education in developing countries should be viewed as a mechanism of liberation and democratisation and not cultural and economical cultivation. Finally, there was a need for research to focus on new approaches to viewing digital competencies in ITE. Hence, this study recommended as a foundational way forward the development of a framework that adapted digital competence so that rather than being technicist, it embodied the values and aims of CP.

Chapter 4

The missing links in South Africa's quest for pedagogical integration of ICTs in schools: Implications for e-education and initial teacher education

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Abstract

Since the 1990s, South Africa has been striving to meet global standards in education delivery by introducing computers in some schools. In 2004, White Paper on e-Education was incorporated into the country's education system and was followed by the rollout of information and communications technologies (ICTs) to start pedagogical integration in schools. Meanwhile, the relevant competencies required by teachers to pedagogically integrate information and communications technology (ICT) in classrooms are lacking

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in initial teacher-training programmes. This chapter presents qualitative empirical evidence of teachers' perceptions of the gaps in South Africa's quest for pedagogical integration of ICTs in schools. Empirical data were generated using individual face-to-face (f2f) and focus-group interviews with 22 teachers from five high schools in the Gauteng province, South Africa. Data were analysed using a thematic content analysis approach. A critical analysis of the *White Paper on e-Education of 2004* (DBE) reveals that despite the role of teachers as major players in ICT integration in schools, teachers' beliefs about pedagogical ICT integration in schools are not prioritised in the *White Paper on e-Education of 2004* (DBE). Evidence from teachers' interactions reveals that they believe that there is a mismatch between government expectations and ICT integration practices in schools. Furthermore, teachers are often neglected in decision-making processes that involve policy formulation and innovation programmes. The implications of the findings for ICT integration and ITE were stressed in the study. The chapter concludes by stating that ICT integration in South African schools is slow because preservice teachers are not well trained to pedagogically integrate ICTs during teaching practice. The authors recommend that baseline research should precede the introduction of new policies and innovation in schools.

Introduction

The integration of ICT in education has received considerable attention from governments globally as a means to enhance learning and teaching (L&T) processes (Du Toit 2015; Munyengabe et al. 2017; Vandeyar 2015). The recognition of the benefits of technology in the education sector resulted in researchers exploring and evaluating the effects of modern technology in teaching and learning (Aslan & Zhu 2015; Mercado & Ibarra 2019; Sife, Lwoga & Sanga 2007). While teachers in different countries report that they have not had adequate training to help prepare them to use technology effectively in teaching and learning, there are efforts where countries are effectively using technology to train teachers to use technology as tools for enhancing teaching and learning (Aslan & Zhu 2018; Hew & Brush 2007). In this chapter, we analysed the *White Paper on e-Education of 2004*, titled: 'Transforming learning and teaching through information and communication technologies' (DHET 2004), which was designed to provide a roadmap for ICT integration at all levels of education in South Africa. The reason is to explore teachers' beliefs about the missing links in South Africa's quest for pedagogical integration of ICTs in schools.

The introduction of the e-education policy was aimed at providing opportunities to access learning, redress inequalities and improve the quality of teaching and learning (*White Paper on e-Education of 2004*). This further implies that the quest for ICT integration in South African schools is aimed at enhancing the nature of classroom practices. The reform needed teachers to acquire appropriate ICT knowledge and skills and to integrate ICT appropriately in teaching, learning and administration of education (DHET 2004). Teachers' knowledge was important to implement the intended goal of the *White Paper on e-Education* (DBE 2004):

> Every South African learner in the general and Further Education and Training bands[10] will be ICT capable (i.e. use ICTs confidently and creatively to help develop the skills and knowledge they need as pupils to achieve personal goals and to be full participants in the global community) by the year 2013. (p. 17)

While it is important to support the government's objective, Dlamini and Mbatha (2017:17) are concerned that 'teachers' ICT PD needs are not addressed in a meaningful and systematic way despite the demand for teachers to develop ICT skills and competencies'. We therefore realised the importance of interacting with teachers to understand their perceptions of the changes they were expected to implement urgently and successfully.

Research design

Research problem

South African schools are still lagging with regard to ICT policy implementation and integration in schools, and teachers' ICT PD has not been appropriately addressed to ensure effective and successful implementation (Dlamini & Mbatha 2018; Mdlongwa 2012). At the school level, school managers and teachers still face challenges in transforming multiple policies into educational experiences within the policy frameworks (Vandeyar 2013). The *White Paper on e-Education* does not address some vital issues like teachers' beliefs in its implementation of ICT pedagogical integration in schools. Consequently, the factors that influence teachers to use or disregard the use of technology in their classrooms were not fully established and empirically proven through research within the context of South Africa. Despite the huge financial investment in infrastructural provisioning, the current use of technologies in South African primary and secondary urban and rural schools remains low (Chigona et al. 2010; Dube, Nhamo & Magonde 2018).

Research aim

The aim of this study is to identify the missing links in South Africa's quest for pedagogical integration of ICTs in secondary schools.

10. The general and further education and training indicates that all learning and training programmes lead to a qualification or part-qualification on Level 1 of the National Qualifications Framework (www.gpwonline.co.za).

Research objectives

The objectives of the study are:

1. to critically examine the *White Paper on e-Education of 2004* (DBE) document for existing gaps between policy and actual practices of ICT integration in secondary schools
2. to explore teachers' beliefs about the implementation of ICT integration in secondary schools
3. to determine the extent to which teachers were exposed to the use of ICT for pedagogical integration in the classroom during their preservice training
4. to understand the nature of training which teachers received for the use of ICT for pedagogical integration in the classroom to implement ICT integration in schools.

Research questions

This chapter answers four research questions:

1. How does the South African *White Paper on e-Education of 2004* (DBE) address teachers' beliefs?
2. What are the teachers' beliefs about the pedagogical integration of ICT in schools?
3. How were the teachers trained to use ICT for pedagogical integration in the classroom during their preservice training?
4. What kind of training did in-service teachers receive for the pedagogical integration of ICTs in the classroom?

Significance of the study

The findings of this study will significantly contribute to future policy design and planning decisions to improve future ICT integration initiatives in South African schools. It will also provide recent information on what, where, when and how to effectively introduce and implement ICTs in education. This explorative research is important and timely in South Africa because pedagogical ICT integration is currently being implemented in schools. Thus, the findings will further assist initial teacher education programmes (ITE) with contemporary information to assist with their planning.

Literature review

It is no longer contestable that ICT has the potential to transform the teaching and learning process; however, many countries fail to prepare teachers for ICT integration at the initial stage of teacher education (Dlamini & Mbatha 2018; Mtebe & Raisamo 2014). It is noted that some in-service teachers leave teacher-training institutions without being properly exposed to the pedagogical integration of ICT in their classroom teaching. However, to obtain some basic knowledge they could use in the classrooms, some teachers undergo ICT integration training during TPD. Cohen and Hill (2001:66) believe that one of the reasons for the failure of education policies is the 'lack of programme and resource alignment to the policies' intentions'. Educational policies must not be stated vaguely as mere symbolic gestures, but they must be aligned with the educational resources and teacher pedagogical practices. We also add that policies must consider and be aligned with the teachers' educational beliefs, as teachers' beliefs influence their choices and actions concerning teaching, learning and pedagogical practices in the classroom.

Relevant policy on pedagogical integration of ICTs in South African schools

In recent years, teachers have been expected to make routine use of ICT in their teaching to keep up with the increasing pace of advances in technology and developments in the use of ICT in schools (Munyengabe et al. 2017; Oyaid 2009). The South African *White Paper on e-Education of 2004* (DBE) is perhaps the first popular policy document to categorically emphasise the need for pedagogical integration of ICT in the classroom. This implies that South African teacher-training institutions have an obligation to equip preservice teachers with the knowledge and skills needed to meet the expectations of the e-education policy. Unfortunately, the policy does not specify how its expectations can be met in the long run. In most South African educational institutions, ICT is mainly taught as a subject instead of being integrated as a pedagogical tool for teaching and learning in all subject areas (Dewa 2019; Kafyulilo et al. 2015).

According to Dlamini and Na-Allah (2015), over 20 different government initiatives and projects have been implemented to integrate ICT tools in schools, including the flagship projects of Khanya and Gauteng Online. Some of the latest ICT integration initiatives at national and provincial levels in South Africa include Operation Phakisa, which mainly focuses on ICT in education, and the paperless school project in the Gauteng province. Both the national and Gauteng provincial initiatives advocate for the pedagogical integration of ICTs to promote higher-order thinking among learners in schools. Operation Phakisa is 'a development-driven programme aimed at improving performance in various sectors of the South African state' (Odendaal 2015:1). In October 2015, Operation Phakisa education was launched to radically transform South Africa's basic education sector and leverage ICTs in schools to improve teaching, learning and administration of the whole education system.

The affordances that ICT can offer to South African schools

The concept of affordance was first conceived and introduced by Gibson in 1986, describing what an environment can offer to the objects around it. In this study, the concept implies the properties that ICT offers to its users, especially teachers and learners performing their different activities. In South Africa, some scholars (Dlamini & Mbatha 2018; Dube et al. 2018; Mdlongwa 2012) have reported some affordances as benefits of ICT in teaching and learning. For example, Telkom (2015) affirmed that:

> When ICT integration is implemented well in a school or any other learning environment, there are two major benefits. First, it benefits the learners as the technology can become an invaluable learning tool in the classroom. Second, it benefits the educators and other staffs in the school as it provides administrative tools that can streamline the entire running of the educational institution. Some of the benefits to students include; increase in motivation, increased active participation and creativity, improved knowledge and skills, increased collaboration and increased responsibility to learning and self-esteem. Some of the benefits to staff and teachers include; Easier record keeping and access, reduced incidences of records lost due to misfiling, lower administrative costs and less paper wastage, easier communication between staff within and across schools and curbing exam paper scams. (p. 6)

The affordances of ICT in schools are diverse, affecting teachers, learners and administrative staff, respectively. ICT affords every member of a school community the opportunity to perform their task with ease and confidence, depending on their knowledge and skills. These positive attributes of ICT have remained an attractive force to many stakeholders in the education sector. Hence, ICTs need to be integrated into classrooms for improved teaching and learning in schools.

Competencies that teachers require to pedagogically integrate ICT in classrooms

While governments are committed to investing financial resources into education in the 21st century, it is imperative to determine the competencies that teachers need to pedagogically integrate ICTs in the classrooms. If teachers must pedagogically integrate ICT in school, they must possess relevant competencies. On this, Koehler and Mishra (2006) propose that in the 21st century, teachers need different kinds of knowledge to teach effectively in the classroom. Mishra and Koehler (2006) developed the technological pedagogical and content knowledge (TPACK) model that describes the integrated interaction between content knowledge, pedagogical knowledge and technological knowledge. Furthermore, Tondeur et al. (2019)

opined that teacher educators are expected to serve as models for technology integration in schools and should possess the relevant ICT competencies needed. Unfortunately, Dewa (2019) noted that teacher educators in South African universities possess minimal or no competencies for the pedagogical integration of ICT in the classroom. Dlamini et al. (2018) described three types of competencies required by teachers to integrate ICT into the classroom. They include:

- **Cognitive proficiency:** This refers to the skills in everyday life; to exhibit cognitive proficiency, teachers must have sound content knowledge (Dlamini et al. 2018:156).
- **Technical proficiency:** This refers to the ability to utilise hardware and software in the core of teaching and learning, as well as digital literacy. Technical proficiency assists teachers in selecting appropriate ICT to help them achieve the desired lesson outcomes (Mnisi 2015 in Dlamini et al. 2018:156; Saad & Sankaran 2020).
- **ICT proficiency:** This refers to the incorporation and application of cognitive and technical skills to effectively integrate ICTs into the classroom to improve educational outcomes (Dlamini et al. 2018:156).

Within the South African education landscape, a study by Na-Allah (2019) has shown that both teachers and learners are deficient in technological knowledge and in all the relevant competencies required to integrate ICT in teaching and learning. Similarly, Saad and Sankaran (2020) reported that in classroom settings, technology proficiency is the ability of teachers to integrate technology to teach and facilitate, as well as to improve learning, productivity and performance. Technology proficiency enables teachers to identify and explore a wide variety of technological tools and devices to determine and select those that best respond to teaching and learning content.

Information and communications technology integration in initial teacher education in South Africa

Initial teacher education is fundamental as a springboard for effective teaching and learning in the future, and ITE training is a key factor for promoting ICT-based skills related to future teachers' work at schools (Brun & Hinostroza 2014; Chigona & Chetty 2012). In the same vein, the pedagogical integration of ICT in ITE is imperative to the production of 21st-century teachers. Based on this background, the *White Paper on e-Education* requires that the use of ICT, as a set of flexible tools for teaching and learning, be integrated into initial professional education and continuing professional teacher development (DoHET 2004:1). This implies that teachers should acquire relevant and appropriate ICT knowledge and skills and be able to integrate ICT appropriately in teaching, learning and administration of education. Dewa (2019) observed that although the *White Paper on e-Education* (DBE) provides for the integration of ICTs at the initial teacher-training level, there is a dearth of ICTs in most educational institutions where teachers are trained in South Africa.

Theoretical framework

The theoretical framework underpinning this research is the unified theory of adoption and use of technology (UTAUT)[11] model propounded by Venkatesh et al. (2003). We acknowledge that models simply describe a phenomenon, unlike theories, which have the capacity to explain and predict (Ngulube, Mathipa & Gumbo 2015), but the focus of the research is not to predict but rather to explore and explain the implication of the phenomenon. Here, the UTAUT was used as a lens to ascertain teachers' beliefs about the phenomenon being investigated. We considered the UTAUT model suitable for use in this study as teachers are social subjects operating in a social context (schools), undergoing social interactions with different stakeholders in different school contexts. UTAUT consists of four core constructs, namely performance expectancy, effort expectancy, social influence and facilitating conditions. The outcome of the four constructs is usually moderated by four other variables: age, gender, experience and voluntariness of use. Conversely, the UTAUT suggests that these four core constructs are direct causes of technology acceptance and use in schools. We therefore used the four core constructs to gain insight into teachers' beliefs about the expected performance and their beliefs about their efforts in implementing the policy in relation to the social expectations and conditions. We also tried to find out the extent to which age, gender and experience shape the use of pedagogy for ICT integration. We therefore used the UTAUT constructs to arrive at the conclusions about what teachers consider the missing links in pedagogical ICT integration in South African schools.

Research methodology

The study used a qualitative approach to explore teachers' views about the missing links in South Africa's quest to pedagogically implement ICT integration in schools.

Participants

The target study group comprised 22 teachers from five public high schools in the Gauteng province of South Africa. The schools were purposely selected

11. UTAUT is a technology acceptance model that was developed to examine the ability of users to accept technology and their intention to adopt new technologies (Venkatesh et al. (2003).

based on the criterion that they are the initial pilot schools for the ICT integration project the Gauteng province of South Africa. Similarly, teachers were purposefully selected because they were using ICTs (smart boards, tablets and computers) in their classrooms during data-collection. Twenty-two teachers participated in both individual f2f and focus group interviews. All participants were given a pseudonym to protect their identities and guarantee confidentiality. Similarly, the identities of all participating schools were concealed and protected using pseudonyms.

Data-collection

We employed two types of interviews and document analysis to obtain data for the study. The process of data-collection involved:

1. **Face-to-face interviews:** Individual f2f interviews were conducted first, followed by the focus group interviews, to illuminate the views presented by participants during individual interviews. Two teachers were involved in individual f2f interviews for each of the five participating schools, totalling ten teachers.
2. **Focus group interviews:** We organised and conducted five focus group interviews with teachers in the participating schools. Participants varied from one school to the other; however, a minimum of five and a maximum of seven teachers participated in the focus group interview in each school. All interviews were audio recorded in order not to lose any data and to focus on what participants were saying. Both individual and focus group interviews were followed by the transcriptions and analysis of the data, which involved coding, categorisation of codes and formation of themes/topics. The themes/topics served as the basis for the discussion and conclusion of the study.
3. **Document analysis:** This involved a critical examination of the *White Paper on e-Education* (DBE). We examined all seven chapters of the government document to identify the disconnection between policy statements and the actual practice during implementation.

Data analysis

Following the transcription of interviews, data were organised and analysed for discussion. Through the transcription process and repeated reading of the transcripts, we immersed ourselves in the content of the transcripts. We individually analysed both data sets and discussed the codes and patterns before we exchanged data for further analyses. A thematic content approach involving the six phases recommended by Braun and Clarke (2006) was used to analyse the interviews. The steps involve becoming familiar with the data, generating initial codes, searching for themes/topics, reviewing themes/topics, defining and naming themes/topics and producing the report. The themes/topics that emerged became the basis for our findings and discussion presented in the next section. To ensure trustworthiness, we used Lincoln and Guba's (1985) four criteria to establish trustworthiness.

Findings and discussion

The findings of the study are categorised into two major areas based on the data-collection methods adopted. Firstly, the *White Paper on e-Education* (DBE) has made different provisions to ensure the effective implementation of ICT integration in schools. We critically examined the *White Paper on e-Education* in the following areas, and the findings were recorded as follows.

Capacity building

In Section 4.7 of the *White Paper on e-Education*, DoHET (2004) acknowledged that:

> [*M*]any teachers have grown up in environments with limited electronic technology and thus find the adaptation to working with ICTs more difficult than their learners do. A programme that urgently addresses the competencies of teachers to use ICTs for their personal work, in their classrooms, must be developed. This will require extensive staff development and support. Thus, ICTs will be central to the preservice training of recruits and the ongoing professional development of practicing teachers. (p. 22)

Findings from the schools reveal that teachers are unsurprisingly at different levels of ICT competencies as the government continues to provide ICT training to in-service teachers in schools through the DoHET. During the individual f2f and focus group interviews, some participants expressed their views concerning different aspects of the training supports. For example, Pilwane said:

> 'We were trained but not well trained; the first time, we were taken to a certain school to go and have training there, while our school was not having Wi-Fi. Where we were trained, they had a Wi-Fi; coming back to our school, we couldn't practise what we gathered [*learned*] from the training.' (Pilwane, female, teacher in school A)

Similarly, Bongani explained that:

> 'Now, it's not that regularly; I normally train when we got something new happening in the class, and I just do a short training on that. Like, if we have a new smart board or a new type of interactive board, I normally do training on that, and we had some training when we received the three-dimensional (3D) software. Normally, as is needed, I do bit of training.' (Bongani, male, teacher in school B)

The responses suggest a mixture of insufficient and 'train-as-you-need' approaches, as the availability of Wi-Fi determined whether and how often teachers could implement what they had been trained to do. The experience of irregular training could result in bits and pieces of information that could be incoherently understood and difficult to implement systematically, holistically and successfully.

Complex support for ICT integration

In Chapter 5, Section 5.4 of the *White Paper on e-Education* (DBE 2004) states that 'each school will have a dedicated teacher outside the normal staffing ratio to manage ICT facilities and champion the use of ICTs in the school community'. This is practically lacking in most of the schools that participated in the study. In this study, only one school has devoted one teacher in school to champion ICT integration activities. During the individual f2f interviews, some participants expressed their views about the nature of support for ICT integration in schools. Bongan said '[...] the school management is keen; we don't have trouble with integration at all. So we get a great deal of support from most of the stakeholders' (Bongani, male, teacher in school B). On the contrary, Kabelo opined that 'internally, the support is only verbal, is not practical; the principal will only support us verbally, but is not practical'. The different views of the teachers clearly indicate the disparity in the support that teachers receive in various schools. While in some schools' teachers receive practical support towards ICT integration in schools, in other schools, that support is limited to mere verbalisation. According to the participants, some schools have some facilitating conditions that support ICT integration in the schools, which suggests an unequal provision of facilities in the schools.

Lack of initial pedagogical ICT integration training

Preparing teachers for their new roles in the 21st-century classroom requires a more explicitly articulated training programme at both preservice and in-service levels. Dewa (2019:9) opined that it is imperative that preservice teachers be provided with various opportunities to learn and use ICT during their training, especially during their teaching experiences. Our findings indicate that teachers are exposed to different kinds of PD, which are inadequate and haphazard, to ensure successful implementation in the classrooms. According to Prakash (2018) teachers require sustained and continual training that can meet the requirements of their new roles, that is, a programme that makes technology an integral part of their professional lives.

The evidence from the analysed data reveals that most teachers did not have prior knowledge of ICT before qualifying for the teaching profession in schools. Some teacher-training institutions in South Africa do not expose preservice teachers to the pedagogical integration of ICTs in the classroom. During a focus group interview, Lungile, a female teacher in school D complained that 'they [government] forgot that some of us did not get the training from the tertiary institution where we were trained as teachers'. This corroborates with the findings of other scholars (Dewa 2019; Ertmer & Ottenbreit-Leftwich 2010), who reported that despite increases in new technologies at universities, ICT is not being used to support preservice teachers as expected. Similarly, in this study, we found that in-service teachers did not know how to pedagogically incorporate ICT in their classroom practices.

Lack of baseline research

In view of the uncertainties that are prevalent in different school contexts, it is important to gain an understanding of the general and specific dynamics of schools before introducing new policies or programmes aimed at school improvement. Baseline surveys help to uncover key information about different variables that have the potential to influence the project or policy implementation.

During both interviews conducted in schools, the research participants reflected and concluded that the lack of a baseline study is a big drawback to the achievement of e-education goals in South Africa. Shaka was of the opinion that:

> 'The way the ICT integration project is being implemented is not in a good way [...] Things are not supposed to be that way. If there can be proper communication and consultations before they can actually implement, it will be better.' (Shaka, male, teacher in school C)

Participants believed that if a feasibility study had been carried out prior to the introduction and implementation of the e-education policy, the government would have been able to ascertain existing contextual peculiarities of the schools and take appropriate steps to mitigate some of the challenges that were being experienced in the schools.

Lack of prior consultation with relevant stakeholders

Relevant stakeholders in education play a vital role in decision-making concerning innovations in education. Wadesango and Bayaga (2013) asserted that teacher participation in education decision-making helps to ensure success during the implementation of policies, curriculum and innovations. In this study, we found that the exclusion of relevant school stakeholders made the implementation of integrating ICT in schools experience some hitches because most stakeholders did not seem to understand the government's vision. For example, during a f2f interview, Kabelo, a male teacher in school E, maintained that:

> '[*T*]he way it is being implemented is not in a good way if the department of education can actually engage with the people in the relevant field and have their own opinion to say how can this be done and I think they can do better. If they can also come to the schools and hear the views of the teachers before they can actually start because somebody up there will favour some idea and the teachers on the ground are expected to implement [...] Things are not supposed to be that way. If there can be proper communication and consultations before they can actually implement the innovation in school.' (Kabelo, male, teacher in school E)

This response suggests that teachers also want their views and those of researchers to be considered, rather than only government views, whether ICT integration is important and how it should be implemented. Particularly, they feel that teachers are involved on the ground and could provide relevant and contemporary advice on what action should be taken and how to ensure successful implementation. A study conducted by Anderson and Minke (2007) found that parents' involvement in education is associated with many educational achievements in schools. They reported that:

> There is a causal relationship between parent involvement in education decisions and higher learner achievement in school subjects, lower dropout rates, increased ability to self-control and higher level of social skills among learners. (p. 1)

Discussion of findings

Within the South African context, the introduction of ICT into high school classrooms is an innovation that comes with challenges, especially during the implementation stage when many stakeholders and material resources are harnessed together in a systematic way. This is evident in the findings of the study where different challenges, like the lack of initial pedagogical ICT integration training and a lack of prior consultation with relevant stakeholders, are identified as impediments to successful integration, as well as the lack of baseline research to ascertain the feasibility of introducing ICT in schools as an innovation. There is a lack of baseline research to inform the planning and implementation of the innovation in relation to distinct school contexts. According to the Cram Essay (2012):

> The purpose of a baseline study is to provide an information base against which to monitor and assess an activity's progress and effectiveness during implementation and after the activity is completed. (p. 1)

In view of the uncertainties that are prevalent in different school system contexts, it is important to gain an understanding of the general and specific dynamics of schools before introducing new policies or projects that are aimed at school improvement.

Through baseline surveys, key information about different variables that have the potential to influence the project or policy implementation is uncovered, making it important to use it to interact with the community. A baseline research survey provides the basis for effective planning and for subsequent monitoring and evaluation of the project (Cram Essay 2012). Most of the participants considered the lack of a baseline study a big drawback to the achievement of the project goal and objectives, even though most of the schools depend on the government for the provision of ICT infrastructure, facilities and tools. Expectedly, findings from baseline research provide useful information about the specific needs of each school.

Related to the lack of baseline research is the lack of prior consultation with relevant stakeholders like teachers, parents and schools host community leaders before the government resolved to embark on the ICT integration initiative in public schools. The exclusion of relevant school stakeholders made the implementation of integrating ICT in schools difficult because most stakeholders did not seem to understand the government's vision. It is important to note that although the political will of the government is important for the implementation of ICT integration in schools in terms of funding, training, facilities and infrastructural provisioning, it is not enough to ensure the safety of resources and success in the implementation.

Implications of the study

Teachers have been central to the implementation of the *Curriculum and Assessment Policy Statement* (CAPS) in South Africa. The *White Paper on e-Education* (DBE) views ICT development as a process that takes teachers and learners through learning about ICT, learning with ICT and learning using ICT (DoHET 2004). Given the policy statement and the findings of this study, the authors established the fact that the challenges and pitfalls observed and experienced by teachers during the implementation of the provisions of the *White Paper on e-Education* (2004) had some implications for ICT integration in schools and the ITE. In view of the findings indicated in the previous section, the implications are discussed.

Implications for ICT integration in schools

The identified findings of the study have considerable implications for ICT integration in schools. This is because successful integration of ICT in teaching and learning requires knowledge and skills of ICTs and other facilitating conditions in the school. Importantly, teachers' pedagogical beliefs need to be addressed if effective integration is to be achieved.

Implications for initial teacher education in South Africa

In the current technology era, HEIs are expected to prepare teachers to use ICT in pedagogy with respect to competencies and to teach ICT-related content. It is imperative that South Africa prioritise PD programmes for preservice and in-service teachers to promote the use of modern technologies in the classrooms. Du Toit (2015) declared that teacher-training institutions are preparatory grounds for initial teacher training on pedagogy, subject content mastery, classroom management skills and the use of various teaching tools, including ICT. Unfortunately, a study conducted by Sang et al. (2010) revealed that teacher education institutions are facing challenges in preparing preservice teachers for the successful integration of ICT into their teaching and learning. Ultimately, an analysis of the *White Paper on e-Education* (DBE) document and empirical findings from interviews provided us with the basis for our conclusion and recommendations.

Recommendations

In view of the research findings, the authors consider it imperative to make the following recommendations for effective ICT integration in South African schools:

1. Continuous baseline research to determine teachers' beliefs and school contextual factors with their implications for classroom practices (pedagogy) is essential prior to policy formulation and implementation.
2. All the tiers of government should make necessary consultations with relevant education stakeholders before introducing any form of innovation in the education system.
3. Schools of Education in the universities and Colleges of Education should rigorously pursue the e-education requirement for integrating ICT into the ITE programmes.
4. Continuing professional teacher development should be based on the e-education requirement for pedagogical integration of ICT into classrooms. This will help teachers to acquire appropriate ICT competencies to integrate ICT in teaching, learning and administration of education.

Conclusion

This chapter explores the missing links in South Africa's quest for pedagogical integration of ICTs in schools with a particular interest in the implications for e-education and ITE. Empirical data were generated using individual f2f and focus group interviews, and the data were analysed using a thematic content analysis approach. Findings reveal that most teachers in the research context believe that there is a mismatch between government expectations and ICT integration practices in schools. The implications of the findings for ICT integration and ITE were stressed in the study. This chapter concludes that ICT integration in South African schools is slow because preservice teachers are not trained to integrate ICTs pedagogically during teaching practice. The authors recommend the need to emphasise the introduction of pedagogical integration of ICTs at ITE to prepare teachers for the use of ICTs in schools at all levels of education.

This study concluded that there is a mismatch between the government's expectation for e-education and the actual teaching practices in schools. This corroborated Vandeyar's (2013) and Dewa's (2019) claim that most teacher-training institutions in South Africa are not adequately exposing preservice teachers to the pedagogical integration of ICTs in the classroom. The preparation of effective teaching manpower from the ITE level is critical for teaching in the 21st century; hence pedagogical integration of ICT in teaching should start at the level of initial teacher preparation. Teacher education institutions should provide preservice teachers with three main skills: basic computer literacy; specific knowledge in relation to teaching with technology; and practical experiences through increased exposure and practice to connect technology and the real pedagogical approaches (Al-Zahrani 2015; Liu 2012). Real integration of ICT into teaching and learning is beyond the mere formulation of policies and infrastructural provisioning (Dlamini & Na-Allah 2015), but it involves a deliberate effort to understand and engage all critical actors and tools in the education system.

Chapter 5

Teacher educators' pedagogical thinking in an ERTL programme: The case of two higher education institutions

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic brought about the transition to emergency remote teaching and learning (ERTL) at higher

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education institutions (HEIs) across South Africa, prompting both students and teacher educators to rapidly adjust to a different modality of teaching and learning. This study explored four purposively selected teacher educators' pedagogical thinking in an ERTL programme during the COVID-19 pandemic and the ways in which this thinking influenced pedagogic practice. This qualitative, interpretative study used data-generation methods of self-reflective journals and Microsoft Teams focus group discussions. Drawing on the conceptual framework of pedagogical reasoning and action, connectivism and connected learning, the findings show that the ERTL programme compelled teacher educators to reconsider their pedagogical practices for continued epistemological access. This included reflecting on the renewed purpose of education by deliberating on core curriculum content, contextual realities of students and practices that enhance student engagement and learning. Teacher educators had to critically reflect and make particular pedagogical decisions and choices in relation to planning, the use of various online platforms to enable connections between curriculum, pedagogy and assessment. However, the ERTL programme caused anxiety and a sense of disquiet that necessitated a reconstruction of teacher educators' personal and professional identities. As such, teacher educators used their sense of agency to renegotiate their personal and professional identity in keeping with praxis and a philosophy that encompasses social justice. This ability of teacher educators to adapt and reconfigure proves that despite times of crisis, their ICT pedagogical approach is fundamental to forward epistemic justice to enhance students' access to learning.

Introduction

The global outbreak of COVID-19 in 2020 was a major health care concern (Cucinotta & Vanelli 2020). In South Africa, the government restricted movement between provinces to prevent the spread of the disease. As a result, all learning institutions were closed. Higher education institutions shifted their education delivery from face-to-face (f2f) teaching to an ERTL programme (Vlachopoulos 2020). Institutions reported varying levels of responsiveness in meeting the requirements for the 2020 academic year using various online approaches (Nzimande 2020). For example, the Universities of Cape Town and Witwatersrand used e-learning platforms such as Moodle, Sakai, Microsoft Teams and Blackboard for advanced education and learning. Other universities, such as the University of KwaZulu-Natal, opted to first prepare students and staff for the ERTL programme before launching the online programme. Regardless of when the institutions decided to launch the ERTL programmes, Soudien and Harvey (2020) contend that higher education (HE) teachers and students were forced to make quick decisions about curriculum and syllabi. Higher education teachers had to adapt to using technology in unexpected ways and quickly learn how to incorporate these new technologies in novel ways for teaching and learning. They had to rethink how they would make their lessons more accessible, ensure meaningful learning and assess students' knowledge using the various LMS and digital platforms provided by colleges and universities (Fataar 2020). Information and communication technology (ICT) units at HEIs were called upon to provide a plethora of crash course training sessions and short webinars to assist lecturers.

Teacher educators had to use their existing pedagogical knowledge, as well as skills and teaching methods related to ICT integration, such as blended learning, hybrid learning, e-learning and flipped classrooms (Protsiv & Atkins 2016). The demand for an online reconfiguration of undergraduate and postgraduate courses had to take cognisance of using technology effectively to ensure issues of social justice, accessibility, inclusivity and pedagogy were adequately addressed.

Although COVID-19 became a catalyst for appreciating digital resources and technology-based teaching and learning, the rapid transition to an ICT-intensive environment posed significant challenges to the work of teacher educators. This study explores teacher educators' pedagogical thinking in an ERTL programme and the ways in which this thinking informed their pedagogic practices during the COVID-19 pandemic. Understanding how teachers use technology in pedagogy is critical, as it opens the door to incorporating ICT in innovative ways into practices following COVID-19.

Significance of the study

This study reveals the agentic nature of teacher educators who had to quickly adapt their pedagogical practices during the COVID-19 pandemic. It shows the opportunities and struggles that teacher educators endured to ensure student epistemological access and success. The study's findings are significant for HE teachers who have traditionally taught f2f but are under pressure to incorporate ICT into their practice. The findings of this study will also enable HEIs to critically reflect on pedagogical shifts that will adequately prepare HE teachers to deal with the diverse exigencies that will emerge following COVID-19.

Literature review

Unpacking emergency remote teaching and learning

There are various concepts in research that explain online teaching and learning and ERTL. While these concepts have different meanings, they are often used interchangeably, for example, distance education, online teaching, emergency online education and remote teaching (Branch & Dousay 2015). Branch and Dousay (2015) argue that when planning for quality online learning, it is important to use a systematic model to guide instructional design. However, in times of crisis that require a quick shift to ERTL, this careful consideration is often neglected (Hodges et al. 2020). Emergency remote teaching and learning is a 'temporary teaching solution to an emergent problem', and once the crisis has ended, f2f or blended learning should resume (Misirli & Ergulec 2021:1). In an ERTL environment, teacher educators attempt to provide students with temporary access to different kinds of learning opportunities. While being a temporary endeavour, ERTL requires flexibility and adaptability through careful 'planning, designing and determining of aims to create an effective learning ecology' (Bozkurt & Sharma 2020:ii). It would then require that the curriculum, pedagogy, assessment and engagement among participants become important. As such, exploring how and why online teaching and learning in HE occurs and its implications for practice is critical, particularly in times of complexity and crisis.

Pedagogy in the time of COVID-19

Pedagogy is defined as an act of teaching, mediated by rules, interaction and teaching and learning tools to achieve learning outcomes. This definition highlights the social and contextual nature of pedagogy (Raikou 2019). While COVID-19 posed educational and pedagogical challenges for teacher educators, it also served as a catalyst for finding new and innovative solutions to ensure epistemological access. This requires a reflection on the preparedness of students for online learning, student support, issues of Internet connectivity and Internet quality, ways of engaging and participating in online platforms, the kinds of knowledge that are valued and forms of assessment. Further, Cucinotta and Vanelli (2020) maintain that teacher educators need to acquire the necessary knowledge and skills for online instruction. Also, Czerniewicz (2020:178) states that to promote social justice, curriculum design strategies need to be 'appropriate for specific contexts, but also being aware that technological decisions will be shaped in ways that reflect existing differences, alliances, discourses and perspectives in particular institutions'.

When thinking about pedagogy in ERTL, a useful model is Mishra and Koehler's (2006) TPACK, which builds on Shulman's (1987) pedagogical content knowledge (PCK). Mishra and Koehler (2006) define TPACK as an integration of technological knowledge (TK) (knowledge of how to use technologies), content knowledge (CK) (knowledge about the subject matter) and pedagogical knowledge (PK) (knowledge about the procedures of teaching and learning). Further, Savec (2020:14) argues that TPACK can be seen as a 'dynamic, integrative and transformative knowledge of the technology, pedagogy and content of a subject matter needed for pedagogically meaningful integration of ICT in teaching'.

Technological pedagogical content knowledge enables the matching of technological tools with pedagogical practices for different content areas, thus allowing for 'technological integration with optimal pedagogical approaches and content representations' (Nasri et al. 2020:348). Pedagogical approaches in an ERTL programme include synchronous, asynchronous approaches or a combination of both. Synchronous approaches have communication and engagement happening in 'real time' through live video conferencing, allowing for instant feedback and clarification (Doucet et al. 2020; Khan 2006). Asynchronous settings are more individually based and self-paced, as they are temporally and geographically independent (Roblyer et al. 2007). The TPACK model is therefore useful for providing insight into the intersection between theory and practice, particularly during ERTL.

Conceptual framework

The theoretical constructs of pedagogical reasoning and action, connectivism and connected learning were used to understand how teaching and learning took place in pedagogically connected and IT learning environments. These theoretical constructs build on each other to facilitate the transformative experience of teaching and learning during the ERTL programme.

Pedagogical reasoning and action

Shulman (1987) believed that teachers' knowledge includes CK, co-joining with how they teach to form specialised knowledge, which he called PCK. Shulman's model (1987:15) comprises actions that a teacher takes during the teaching process and includes comprehension of subject knowledge, the transformation of subject knowledge into teachable representations, instructions, evaluation of students' learning and teachers' practices, reflection and a new comprehension of teaching experiences.

Connectivism provides an understanding of learning as influenced by technology and pedagogy (Siemens 2006). The assumption is that knowledge is circulated within a network comprising connections between entities called nodes (Siemens 2006). These nodes can be organisations, websites, databases, individuals, groups, ideas, resources, communities or any source of information (Siemens 2006). Learning occurs when knowledge is set in motion through participation and collaboration with others in a learning community.

Connected learning is a pedagogical approach to learning within networks (Oddone, Hughes & Lupton 2019). Connected and networked learning assumes that 'learning and education is self-determined, social, relevant, equitable and accessible' (Gogia 2016:19).

Connected learning therefore allows for an understanding of how participation is motivated by a shared purpose and mutual interests within a space that encourages the co-construction of knowledge and understanding (Itō et al. 2013).

The concepts of pedagogical reasoning and action connected learning and connectivism presented a pedagogical approach during ERTL. Shulman's concepts of pedagogical reasoning and action informed the teacher educators' professional judgement about students learning during times of uncertainty while still adhering to institutional expectations. The re-evaluation that emerged informed the use of ICT synchronous and asynchronous learning, creating a transformative learning community. This learning community allowed for teacher educators and students to transverse ICT network connections to access, share and use knowledge for learning (Siemens 2006). The development of a learning community was particularly significant because it engendered a culture of shared purpose and mutual interest within the situated practice of ERTL.

Research design

This study used a case study approach. Rule and John (2011:135) indicate that a case study is a 'systematic and in-depth investigation of a particular instance in its context in order to generate knowledge'. Case studies allowed for a deep understanding of the real-life experiences of four teacher educators working in an ERTL space during the COVID-19 pandemic. Rapanta et al. (2020:924) argue that the ERTL programme has 'often been improvised rapidly' with a focus on how to use technological tools but with little or no 'pedagogical hints on how, when and why to use each of these tools. It is against this backdrop that this chapter sheds light on the pedagogical thinking and reasoning that four teacher educators used to design and implement teaching, learning and assessment activities during the ERTL programme. Being unable to generate data in traditional ways, we sought alternative distance data-generation-oriented approaches. Roy and Uekusa (2020:4) suggest that in distance-oriented approaches, the 'researcher is simultaneously the instrument and the data source'. Thus, as both researchers and data sources, we used online focus groups and journals to reflect on our experiences within this new pedagogic space.

Research participants

We used both purposive and convenience sampling. Selection criteria included four teacher educators who were involved in teaching at postgraduate and undergraduate levels and who had to transition quickly to an ERTL platform. Additionally, convenience sampling was used as participants 'were at the right place at the right time' (Acharya et al. 2013:332). Three of the teacher educators worked at the same university and served as mentors to each other during the ERTL programme. The fourth teacher educator from another university was conveniently selected as she also worked closely with them during the ERTL programme. Table 5.1 presents the profile of the teacher

TABLE 5.1: Profile of research participants.

Teacher educator	Gender	Teaching experience in higher education	Prior online teaching experience	Teaching discipline
Teacher A	Female	11 years	No	Curriculum studies
Teacher B	Female	-	No	Foundation Phase studies
Teacher C	Female	15 years	No	Foundation Phase studies
Teacher D	Female	10 years	No	Social justice education

educators involved in the study. To ensure the confidentiality and anonymity of the participants, pseudonyms Teacher A, B, C and D were used.

Data-generation tools

Data were generated through reflective journals and an online focus group discussion. Reflective journals are widely acknowledged as an effective means of allowing people to think deeply and critically about their own practices, subjective thoughts and feelings (Cohen, Manion & Morrison 2018; Ortlipp 2008). We started our self-reflective journals during lockdown level 5. Over the course of three months, we wrote about our experiences of teaching, planning, attending various reskilling workshops offered by our institutions and delivering lectures and the emotions, experiences and challenges we encountered. Self-reflective journals became the space where we could use our teaching experiences to reflect on the 'connectivity between self and others' (Chang, Ngunjiri & Hernandez 2013, cited in Roy & Uekusa 2020:386).

A focus group discussion using Microsoft Teams was set up once teaching was completed for the first semester. According to Stewart and Shamdasani (2017), online focus groups tend to be more difficult as in-depth engagement can be absent and discussion can be strained. However, our longstanding working relationships negated this disadvantage. Instead, a sense of ease and comfort provided a safe space for researchers to talk about experiences openly, despite the geographical distance. This is in keeping with Xerri's (2018) views that focus groups are about self-disclosure, where an emotionally safe environment is key. We spoke freely, debated issues and discussed ideas from our self-reflective journals. The advantage of using focus group discussions was that we tended to feed off each other's experiences of the challenges and opportunities of using technology. Focus group discussions were audio recorded and stored.

The focus group discussion was then transcribed verbatim. We again set up a Microsoft Teams meeting to verify, add to or remove data that were not reflective of our aims. Data analysis was initially performed individually, where we looked at one another's self-reflective journals and the focus group discussion. We identified categories and codes, drawing on conceptual constructs and literature on ICT and pedagogy. After this, we set up another

Microsoft Teams meeting to make collective decisions about the final themes, which were:

- epistemological access
- pedagogical thinking and action
- pedagogy and the uncertainty of identity.

Ethical considerations

The ethics committees at both institutions granted permission to conduct the study.

Member checking and discussion ensured that misrepresentation was alleviated.

Findings and discussion

In the section that follows, we infuse the findings with relevant literature and *pedagogical reasoning and action* (Shulman 1987), *connectivism* (Siemens 2006) and *connected learning* (Oddone et al. 2019) to provide a nuanced understanding of teacher educators' pedagogical thinking and action during ERTL.

Epistemological access

Based on the HE teachers' critical conversations and reflections, the issue of epistemological access was identified as a key consideration for technological pedagogical thinking:

> '[*T*]he first aspect I considered was what kind of learning should be pursued in an online platform [...] I began to rethink my learning outcomes and objectives to consider how ICT could make knowledge accessible and relevant.' (Teacher A)

Teacher A's pedagogical thinking was centred around meeting students' various needs and making learning more relevant. Her reflection shows her agentic nature as she reconsidered her CK and learning outcomes to include ICT as a relevant L&T tool.

Teacher B gave more consideration to the financial and emotional cost of ERTL for students and academics: 'Data connectivity and context issues required me to rethink how I designed, planned and implemented my online lessons [...] No learner should be disadvantaged'.

Teacher B was well aware of the financial constraints of studying in a remote location and recognised that 'no learner should be disadvantaged'. Consequently, she took learner accessibility and socio-economic conditions into consideration when planning for ERTL. Reimers and Schleicher (2020) argue that we cannot have epistemic justice if our students are without devices, Internet connectivity and physically conducive environments. Shulman (1987:102) further argues that 'the ability of a teacher to transform the CK they possess into forms that are pedagogically powerful while remaining adaptive to the variations in ability and background presented by [students]' is critical to the teaching process.

In terms of rethinking the relevance of knowledge, Teacher C talked about pedagogical sensitivity in the use of ICT:

> '[*M*]y technological pedagogical thinking was influenced by establishing an iterative relationship between everyday knowledge and institutional knowledge by considering the everyday life circumstances of my students; I had to rethink my teaching accordingly.' (Teacher C)

Teacher C's technological pedagogical thinking included a strong emphasis on sensitivity to students' everyday life circumstances. This was included to avoid a cultural divide between herself and students (Saavedra 2020).

Teacher D (who was at a different institution from Teachers A, B and C) added:

> 'I began to consider my objectives first and how the use of ICT could help me achieve them; of course, issues of accessibility and content had to be addressed. I also considered how our students' lived experiences influenced their learning [...] Let me tell you about an incident that happened with one of my postgraduate students. Due to a lack of data connectivity, my student was unable to attend postgraduate classes [...] She sobbed as she told me this [...] As a teacher educator, I am morally and ethically obligated to ensure that students do not fall behind. The classmates and I chipped in to get her to an Internet café so she wouldn't miss any lectures. I then used this student's experience to teach about oppressive structures via virtual learning.' (Teacher D)

Teacher D's strong desire to use ICT to successfully address issues of social justice inspired her to look into ways to improve pedagogy and make learning contextual (Bozkurt & Sharma 2020). Her 'moral and ethical obligation' as a teacher educator underpinned her pedagogical thinking, which was deeply moved by a sense of fairness for the development of a more just society.

All participants recognised the need to change or transform their teaching practices and were aware of the university's mission of teaching and learning. Through their reflections, they were able to understand how to reselect and adapt CK to meet the needs of students (Shulman 1987).

Pedagogical reasoning and action

The teacher educators talked about how they made pedagogical choices based on their knowledge of students, technological PCK and curriculum knowledge when planning the ERTL programme. The following subthemes reflect the choices that were made.

Pedagogical reasoning about planning

The teacher educators had the following to say about their pedagogical reasoning behind their planning processes:

> 'I redesigned my course to consider how I was going to use ICT as both a teaching and learning tool [...] so my practices also had to change.' (Teacher C)

Additionally, Teacher B planned for synchronous learning considering the lived experiences of her students: 'I had to also consider how I was going to maximise students' learning using minimum resources.'

Teacher D talked about how her pedagogical reasoning about planning was based on the achievement of learning outcomes and shifted between synchronous and asynchronous teaching and learning to ensure:

> '[*S*]ubstantive knowledge-building, sequencing of knowledge and cumulative learning was a priority. But also to ensure quality of my programme. [...] it had to always be student oriented, but my outcomes always had to guide and facilitate my planning.'

The data reveal that pedagogical reasoning about planning comprised making decisions about core CK, the purpose of what is to be taught, needs of students, CK of interrelationships within the subject for substantive knowledge-building, sequencing of knowledge and cumulative learning, using ICT as a teaching and learning tool and maximising students' learning using minimum resources. Additionally, intensive self-reflection and evaluation of pedagogical practices brought new comprehension where the role of the teacher educators had to shift to 'decision-makers who design their technological learning environment as needed, in real time, by focusing on approaches to teaching that endure through changes in learning context, learning content and pedagogies' (Mishra, Koehler & Kereluik 2009:52). What is also evident is that the teacher educators used ICT to support the achievement of educational goals and outcomes, students' knowledge, skills and understandings and their choices of pedagogical practices. As argued by Seale and Cooper (2010), ICT as a teaching and learning tool becomes the pedagogical means that mediates action, providing principles for learning that were then translated into practice.

Less is more

The teacher educators talked about how they had to consider institutional teaching and learning guidelines and regulatory frameworks when designing meaningful ICT-mediated activities. They had to redesign content, learning activities and assessments with the idea that 'less is more'. The teacher educators reflected on how they had to conceptualise what the construct of 'less is more' meant in ERTL. They had to transform knowledge into a form that could be taught to include education purpose, knowledge of content and student needs and characteristics (Shulman 1987):

> ‘[*W*]e were asked to cut down on content but still try to achieve the outcomes of the course. So for example, I planned for teaching content in a more integrated way rather than focusing on content knowledge in silos.’ (Teacher C)

For Teacher B, large classes presented a particular challenge when planning for *less is more*:

> ‘We couldn’t have Zoom meetings because of large classes, so I gave them independent work, small group activities, tutorial sessions, video clips and online talks that focused on core content.’ (Teacher B)

Teacher D had to go with her institution’s idea of *less is more*:

> ‘I had to think about how students would acquire the core content and knowledge without compromising their learning. I was guided by my lesson and module outcomes [...] few texts required deeper engagement with core content and knowledge [...] less is more became valuable way of thinking about what I was going to do [...] The more they engaged with the given text, the more critical and reflective they became of what they were reading.’ (Teacher D)

The construct of *less is more* meant that teacher educators had to strategically orchestrate learning by balancing core course content with learner responsibility and self-regulated learning. This knowledge facilitation aims to ‘change and challenge students’ conception of their learning [...] a process in which students construct their own understanding [...] the focus is on insight, critical thinking, and knowledge application’ (Santos, Figueiredo & Vieira 2019:13). Thus, their curricula decisions were closely connected to the CK transformation that was characterised by an understanding of the purpose of education during ERTL (Shulman 1987).

Enabling connections between teaching, learning and assessment

Transforming CK into teachable content is key to enabling connections between teaching, learning and assessment. The following statements reveal the ICT resources that were selected and adapted to support pedagogic practice:

> ‘[*U*]sed different ICT resources to help students acquire the content knowledge [...] like videos, two- and three-dimensional images, graphs, narrated Microsoft PowerPoint slides, worksheets, data information.’ (Teacher C)

> ‘I planned for synchronous learning with narrated Microsoft PowerPoint slides, discussion forums, activity-based tutorial sessions [...] so that students could study at any time [...] day or night and when they had data and connectivity.’ (Teacher B)

> 'I used WhatsApp groups, narrated Microsoft PowerPoint slides, videos, Moodle, discussion forums and education blogs to supplement my pedagogic practices. Discussions on blogs and forums were based on online reflections that the students shared prior to each session [...] Each student was then given a turn to lead the discussion.' (Teacher D)

Teacher A concurred and added:

> '[*M*]y practices required for students to dialogue, share ideas, solve problems [...] they also had to work independently. For me, online talks, videos, voice-over Microsoft PowerPoint slides and discussion forums proved useful. I would post a question on the discussion forum and students would have to answer these questions. They were given a credit mark for participation on the discussion forum.'

These statements show how ICT resources such as digital e-learning platforms and online resources like videos, graphs and images were used to support pedagogic practices and enable connected learning. These practices provided rich learning environments and motivation for the teaching and learning process, which had a positive impact on students learning. Students would engage, collaborate and support each other, thereby enhancing individual learning and group collaboration.

The teacher educators also talked about how they used assessment to enable students to demonstrate their understanding and learning of course content. Key issues that emerged included constructive alignment between course outcomes and assessment, transparency of assessment criteria and the importance of constructive feedback to enhance learning (Molloy, Boud & Henderson 2020):

> 'I used rubrics and assessment criteria for assessment. This helped and I was able to discuss and provide feedback on students learning. Assessment served a dual purpose: formative in that they guided students learning and the quality of their work and summative to monitor their learning of course content and how they were able to work independently and use course knowledge in practical ways.' (Teacher A)

> 'Online assessment such as multiple-choice questions, quizzes and group assessment tasks were useful. This enabled a better understanding of students learning.' (Teacher B)

> '[*P*]eer assessment and peer feedback were invaluable [...] but I had to design criteria so students knew what was expected of them.' (Teacher D)

> '[*S*]tudents had to develop an electronic information booklet, and my assessment criteria was built around the extent to which their productions reflected their learning. Students commented and reviewed each other's work, and this was valuable for their learning.' (Teacher C)

These statements show that assessment was used to promote learning but also served as a way of providing students with equal opportunities to demonstrate how well they attained learning outcomes. In this connected online learning process, activities were designed so that students and teacher educators became co-constructors of knowledge, taking responsibility and accountability for learning (Gogia 2016). It also provided opportunities for students to engage with peer learning and constructive peer assessment (Killen 2016). Additionally, the assessment tasks offered the teacher educators the opportunity to make inferences about students learning of content and competencies and skills.

Reflection and action

An important form of reasoning identified by the teacher educators related to reflecting on the integration of content, pedagogic practices and assessment:

> 'Reflection served a purpose of getting students to talk about how well the ICT platforms provided learning affordances.' (Teacher A)

> '[*S*]tudent reflections helped me think about my own practices and the extent to which my practices contributed to learning.' (Teacher D)

> 'I used reflection to get students to conduct a kind of self-assessment of their learning. This helped me to redesign learning activities, course content and assessment.' (Teacher C)

> '[*S*]tudents reflected on the course content and the ICT resources that were used [...] at times I had to change the resources to support goals of my lesson. For example, I found that students were not participating in the discussion forums [...] so I designed online tests and questions to assess their participation and understanding.' (Teacher B)

Reflection thus served as a conceptual lens to make sense of how ICT was infused into pedagogic practices: *to support learning*; *reflection on action*; *self-assessment of learning* and *using ICT resources to support learning goals*. These reflections guided considerations of how TK connected with CK and PCK. In addition, this reflexive process leads to better comprehension of the course content and curricular goals, leading to a deepening of PCK, showing the interdependency between pedagogical content and TK (Mishra & Koehler 2006; Shulman 1987).

Pedagogy and the uncertainty of identity

Emergency remote teaching and learning caused a sense of uncertainty for lecturers that affected them in profound ways, disrupting previously held ideas about teaching and how they understood themselves and what constituted teaching in such spaces. Relationships and the ability to create a bond and connection with students were seemingly absent with online teaching. Teacher D and Teacher C felt the disconnection with their students caused them to reinterpret 'my sense of self':

> 'This online teaching has really caused me to think differently about my sense of self. My sense of self is constructed around the way I see myself and how students see me and how I come across, what I teach and how I teach. My role is constructed

> around interaction and feedback I get from students. This impacts on me and who I am because interaction is so important. It's like re-evaluating my terms of reference – what are my responsibilities and what are students' responsibilities?' (Teacher C)

This sense of loss was acutely felt by Teacher D:

> 'When you are distant from them. They are behind a computer screen – that virtual reality which I am not used to – that distance becomes so large – the validation becomes so much more important. When you ask questions, and they don't respond or if they are silent, you all of a sudden realise that pedagogically, you are uncertain. Before, during f2f teaching, you would know immediately how to change and do something differently, but not now, when you can't read your class. When silence is there – does it mean they don't understand, does it mean that they are thinking, does it mean that they are not even there? I feel that my identity as a lecturer at this moment in time is a bit uncertain, fragile and fluid. And it is really based on what sort of feedback I get, or I don't get, from students now that they are behind the screen, so to speak. Silence is what I see as telling on whether or not I'm getting through to them. Remember, I use participatory pedagogy and I found it difficult to do now. Silence, which was my critical component as it allows students time to think, to mull over ideas, suddenly became disconcerting and uncomfortable. A treasured tool suddenly became my monster. So many things were going through my mind. Do I fill in the silence? If I don't, their data will be soon used up. It was really difficult. What am I doing?'

The reflections on ERTL caused uncertainty and anxiety. Alsup (2006) indicates that when teachers are confronted with events or situations that disrupt their taken for assumptions about teaching, their professional identity is brought into question. Emergency remote teaching and learning caused the lecturers to reconstitute their personal and professional identities based on their experiences of working in an ERTL environment. Teacher C and Teacher D felt a sense of disconnect with students because they were physically absent. Instead, for both these lecturers, teaching became a disembodied act that was counter-intuitive and contradictory to what they believed the teaching and learning process held. The missing element of a physical presence was acute in this study, and this concurs with Nipper (1989) and Palloff and Pratt's (2013) argument that teachers' synchronous presence is important as teacher educators internalise beliefs about themselves and their practices. As such, teacher educators' conceptions of their personal and professional identity became important to developing an 'electronic pedagogy' (Palloff & Pratt 1999:12). The lack of physical presence challenged the foundations of their beliefs about teaching. Moreover, for Teacher D, changes to pedagogical practices which had hitherto been effective and treasured especially left her feeling disempowered and uncertain, where it instead 'became my monster'. This, in turn, influenced how her knowledge base was experienced and her professional identity was interpreted, causing her to reimagine her practice (Shulman 1987). Different from research by Richardson and Alsup (2015), lecturers in this study had previously used student-centred pedagogy and believed that online learning removed that from them.

Teacher A, however, felt that her identity was questioned pedagogically in a different way:

> 'You know that two-week crash course or however long you had it for Teacher D, where you said we learned how to use online platforms, Sakai, Microsoft Teams and so on. Yes, we were not taught about the pedagogy behind it. But what was forgotten also was our identity as lecturers, our teaching identity that was disrupted. We had to quickly adapt, do the research and find understanding about the pedagogy behind ICT. The pressure was immense. I kept thinking, "Is all that I am doing about teaching now?" What about the core of the university – our identities as scholars. What is a scholar now in this time? I don't quite know. I can't even find the time to do the scholarly work of research because I'm trying to develop myself professionally. For me, the students are most important – that epistemic justice that I spoke about earlier must be first and foremost. Yes, we have to think about what good teaching is now, when there is no [*actual*] classroom like we know it.'

For Teacher A, there was a disjuncture between her personal and professional sense of identity. This is because external demands from the university in the form of a two-week crash course to ensure teaching and learning took place conflicted with her knowledge of pedagogical development and her professional identity. Not knowing the pedagogy behind ICT caused Teacher A to be concerned and disrupted her internal meaning-making process (Beauchamp & Thomas 2009). This was compounded by institutional pressure that was immense and caused emotional disquiet. Her professional identity as a lecturer was brought into question because signifiers like being a scholar, a researcher and a knowledge producer were peripheral during the ERTL programme, as time spent on learning how to develop a different professional identity that catered for the student and new online pedagogical thinking took precedence. This is significant for Wenger's (1999:163) notion of identity as a constant 'becoming; the work of identity is ongoing and pervasive'. Thus, for Teacher A, the decision to focus on reconstituting her professional identity as contextual realities required that she provide 'epistemic justice', and this becomes foregrounded, although the pressure to be a researcher and scholar still loomed.

Beauchamp and Thomas (2009) indicate that context and contextual factors influence the shaping of one's identity. Teacher C is aware of students' realities, where social issues abound, and these influence practices as students and lecturers are 'without laptops, without data', where 'students don't respond to email or WhatsApp message'. This initially caused her to feel uncertain, but she used her sense of agency to renegotiate her professional identity once more in keeping with 'praxis and a [philosophy] that encompasses social justice'. Teacher C's distinct awareness that perhaps the institution that she works at has worked with the incorrect assumption that 'all students were on board, all lecturers were on board' is important, for while the institution may have misrecognised students' and lecturers' needs, the teacher educators themselves did not. Dixon and Senior's (2011) understanding of embodied pedagogy places relationships at the centre of teachers' work. It should be one where the needs of students and teachers are considered.

Conclusion

The analysis and discussion of teacher educators' thinking and action in an ERTL environment during the COVID-19 pandemic revealed that they made appropriate pedagogical choices based on their understanding of knowledge structures. Three broad themes emerged from the analysis and discussion, providing insight into teacher educators' responses to the COVID-19 pandemic. Teachers' pedagogical thinking and reasoning demanded that lesson planning become more than a checklist of university requirements compliance. There was a clear reflection on curriculum content and students' socio-economic backgrounds in order to be responsive and provide epistemic justice. Teacher educators also argued that decision-making about pedagogical innovations was deeply connected to the knowledge to be learned, the needs of students, a commitment to principles of inclusion, social redress and justice, as well as the opportunities available within the HE context. Furthermore, the findings highlighted that teaching and learning during ERTL provided an opportunity to reconsider ICT pedagogical approaches and critically reflect on professional teacher identity and epistemic justice. Findings also revealed teacher educators' resilience and adaptability, which bodes well for post-COVID-19 teacher education.

The findings suggest that a holistic teacher education system with a focus on both synchronous and asynchronous modes of delivery is needed. This would help in some way in developing a system that is sustainable, inclusive and equitable. It must be noted that this is a small-scale study; hence, findings cannot be extrapolated to other contexts. However, it provides important and authentic insights into teacher educators' contextual responsiveness and their pedagogical thinking and action, underpinned by and aligned with their embodied pedagogy at the time of an [inter]national emergency.

Chapter 6

The affordances of iPads for learners, teachers and teacher educators in the documentation of visible learning and teaching

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Abstract

This chapter engages the pedagogical affordances of iPads as used to document learning and teaching (L&T) at three levels: by learners to document their own learning, by a teacher to document and understand her own classroom practice and their potential use by teacher educators to train teachers in a systematised classroom pedagogy for young learners. We report and draw on a classroom ethnographic research project conducted in a Grade 7 Reggio Emilia class at a

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Johannesburg school. This study investigated the affordances of iPads in actualising the *documentation of visible learning*. We adapt a model of the pedagogic affordances of iPads described by Drennan and Moll to describe the learning of learners in the classroom and the pedagogy of the teacher herself. This has significant implications for the way in which teacher educators might employ iPads in training student-teachers to document and understand their own emerging classroom practices as novice primary school teachers.

Introduction

A compelling metaphor tells us, 'we should not let the technological tail wag the pedagogical dog' (Moll 2012:17). The general research problem discussed in this chapter, which is salutary in any context in which information and communications technologies (ICTs) are brought into classroom teaching and learning practices, is to investigate how such technologies can be introduced (integrated) in such a way that they do not dictate the prevailing pedagogic engagement with knowledge in schools. In contemporary times, when the ideology of the 'Fourth Industrial Revolution' (4IR) seems to dominate so much thinking about education, it is often difficult to resist reductionist, *technology-driven* conceptions of teaching and teacher education (Moll 2021). So Schwab (2018), for example, wants us to think that the two most critical elements of a 21st-century curriculum must be the ability to use technology and the study of technological change. In contrast, the general underlying principle of this study assumes that one starts with thinking about learner-specific principles about knowledge and learning and then poses the question as to whether the iPad can appropriately enhance such a curriculum. The suggestion is that the most compelling way to think about ICTs in a nonreductionist manner is to consider the *affordances* that they offer teaching and learning. This principle is investigated here in relation to the learning of learners, the learning of teachers and its implications for teacher education. In relation to the objectives of this book, the study suggests how best the realisation of such affordances can be incorporated into an ITE programme.

We report here on a study conducted by the first author in her own Grade 7 Design and Technology classroom at a Johannesburg school (Phakathi 2014). This ethnographic research project investigated the affordances of iPads in actualising the documentation of visible learning, a central pedagogic strategy in the Reggio Emilia approach to early childhood education (hereinafter 'Reggio'). The study reveals how learners documented their own learning and how their teacher documented and understood her own classroom practice in the course of lessons on the design of physical structures. We adapt a model of the pedagogic affordances of iPads articulated by Drennan and Moll (2018) to 'make visible' the learning of learners in the classroom and the pedagogy of the teacher herself. In conclusion, we explore the way in which teacher educators might employ iPads in assisting student-teachers to realise a systematised classroom pedagogy for young learners.

Research aims and objectives

The broad aim of the study was to produce an ethnographic 'thick description' (Geertz 1973) of the ongoing practices of a mid-level primary school teacher using iPads to teach in a Reggio curriculum context, that is, employing the teaching methodology of visible learning to realise learning outcomes. Then, by analysing this ethnographic data, establish a typology for the analysis and development of the affordances of iPads in the documentation of visible learning in the classroom. The objectives of this typology include the furtherance of understanding Reggio teaching using iPads in a classroom and the training of teachers for primary schools in this regard.

The primary school in which these studies were conducted adopted a Reggio-inspired curriculum just over a decade ago. In 2008, the head and some teachers from the junior school visited Reggio Emilia in Italy and, upon their return, sought to explore ways and means to implement the Reggio approach to teaching and learning in the early years centre from about June that year. It was then gradually introduced in the Foundation Phase and aspects of the documentation of the visible learning approach were introduced into the higher grades in 2014. Alongside these developments, iPads were introduced for use by all teachers and learners in ongoing classroom activities from the year 2011. The school's curriculum imperatives thus required the integration of the technological and pedagogical affordances of iPads into Reggio classroom practices in an exploratory way. The present project contributed to these early learnings at the school.

Significance of the study

A thorough literature research makes it clear that there is apparently no specific literature on the use of iPads in documenting visible learning in a Reggio classroom. This study breaks modest ground in this regard. In more general terms, it contributes to the further development of a model of the affordances of iPads in the classroom developed by Drennan and Moll (2018), which can be useful in Reggio and other contexts. Broadly, the research contributes to understanding the pedagogic possibilities of digital technology within a primary school classroom environment.

Theoretical framework

When we think about how we might integrate ICTs into our teaching and learning practices, we should commence with an understanding of how a specific pedagogy is structured and how it operates to recontextualise knowledge in the classroom. So we seek to avoid the reductionist view that considers pedagogy to be inherent in the technology. The potential that any ICT might have to assist us in that task – that is, its *affordances* – become the nub of how we decide to use it in any classroom. The unwanted alternative view is that teaching and learning offer affordances to ICTs, which is what the prophets of the so-called 'fourth industrial revolution' seem to want us to think. This phrasing is reminiscent of McDermott's (1993) famous phrase, 'the acquisition of a child by a learning disability' and is used with the same polemical intent. The specific theoretical framework for the study is then rounded off by consideration of the actual pedagogy that is under investigation, namely the *pedagogic documentation of visible thinking*. While the version that we examine here is distinctive of Reggio, some educators have suggested that it 'refers to any kind of observable representation that documents and supports the development of an individual's or group's ongoing thoughts, questions, reasons and reflections' (Tishman & Palme 2005:1).

Literature review

Pedagogical affordances of technology

It is important to understand that a 'pedagogical affordance' *is not a pedagogy*. The single biggest danger of the deployment of ICTs into the classroom in recent times is the belief that they bring with them some inherent, new, revolutionary pedagogy. The manner in which a teacher (or a community of teachers, who work together, strategise lessons and learning activities together and support each other professionally) utilises the technological and pedagogic affordances of such technologies is for the most part intuitive and unconscious – as Gibson's account of affordances tells us they tend to be. When they work to construct their classroom practices over time – a sociological messaging system comprising a curriculum, a pedagogy and evaluation events (Bernstein [1975] 2005) – they are generally unaware of how they are using the affordances of educational technologies, of whatever kind.

The concept of *affordance* was formulated in 1977 by the ecological psychologist James Gibson (1977, 1979) to describe the quality of an object that allows a person to use it to implement an action. Despite ongoing debate about the concept, Michaels (2003) formulated this definition which is close to an emerging consensus reached by theorists in this terrain in recent times:

> Affordances are the actions permitted an animal by environmental objects, events, places, surfaces, people, and so forth. An action is understood as a goal-directed movement (or non-movement) that entails intention, the detection of information, and a lawful relation between that information and the control of movement. (p. 146)

The crucial point is that while actualising an affordance involves an act of recognition, it is, ontologically speaking, *in the technology, not in the actor*. This becomes crucial when we seek to understand how teachers realise the pedagogical affordances of ICTs in their classrooms.

When they employ ICTs in their classrooms, for their own work or to assist in the work of their learners, the affordances are multiple. Battro (2004) provides us with a wonderful account of the most basic affordances of computers in learning, such as the properties of a mouse, a keyboard, a display monitor, a cursor and selection buttons, which in turn produce the affordances of pointing, dragging, typing, font-sizing, zooming, highlighting, viewing and clicking. There are two levels of affordance here, which we might call technological and pedagogical affordances, respectively. Battro's (2004:79) thesis is that the 'global impact of digital technologies on human society, and particularly on education, is related to … the ability to decide to produce a simple change of state in a system'. He calls it the 'click option'. Both learners and teachers employ these affordances constantly in a digitally enabled classroom (Oliver 2005).

Some authors have extended the understanding of pedagogical affordances of ICTs well into the terrain of complex, depth pedagogies. Laurillard's (1993) *conversational framework* describes the affordances of different media forms for teaching and learning in classrooms and seminar rooms without implying that such affordances amount to pedagogies in themselves Laurillard et al. (2000) extend the discussion of affordances by seeing their usability in terms of operational thinking. The pre-tablet work of Conole and Dyke (2004) examined early online tools and compiled a taxonomy of ICT affordances in education. They listed ten broad affordances for pedagogy and teachers' work. Drennan (2018) suggests that three of these (speed of change, monopolisation and surveillance) fall into the domain of organisational change, while the rest (accessibility; diversity; communication and collaboration; reflection; multimodality and nonlinearity; risk, fragility and uncertainty and immediacy) lie within the domain of teachers' classroom pedagogy. Godsk (2013) examined iPads, Android tablets, Blackberry Playbooks and Touchpads, without differentiation, and claimed their 'Top 10' pedagogical affordances to be inclusive or collaborative learning; multimedia or interactive content in teaching; student satisfaction; personalisation and student-centred learning; use of e-books; resource-saving; mobility; flexibility in time and place; eco-friendliness; and resource competitiveness. Haßler, Major and Hennessy (2016) similarly claimed affordances for teachers using 'transformative pedagogical models' in all tablet brands.

Moving now to the specific affordances of iPads, there is a rich and growing literature on their capabilities in education contexts. In fact, the broader literature now deals mostly with iPads, which Nguyen, Barton and

Nguyen (2014:1) attribute to the 'fast and wide uptake of iPads among the younger generation of students and academics'. Valstad and Rydland (2010:25) credit its multimodal 'convergence tools [for] [...] researching, producing, communicating, teaching and learning'. Mobility is a strong theme in this literature. Brand and Kinash (2010:147) call them 'mobile devices [...] that liberate the learner to realize enactment of anywhere, anytime learning' (also known as polysynchronous learning). The small size of the iPad makes it less cumbersome and more portable as an interactive device for teacher-student and student-student relationships. It affords mobile learning in multiple learning spaces both inside and outside the classroom (Alyahya & Gall 2012; Heinrich 2012; Redman, Carlin & Jakab 2013). Echoing Battro's 'click option', Reid and Ostashewski (2011:1689–1690) praise the 'light finger touches (such as taps, swipes, pinch-zooms)' of the iPad's 'robust textbook-sized screen' and its display, audio and Global Positioning System capabilities as affordances that make the device an 'information gathering [and] media library'.

Research reveals several iPad learning affordances for learners and teachers. Churchill, Fox and King (2012:252) suggest that 'iPads lead students to be more responsible for their learning', and a number of other authors echo this in their findings that the devices enable more intuitive control and ownership by learners of the learning process (Clarke & Abbott 2016; Henderson & Yeow 2013; Redman et al. 2013; Reed 2013). There are also strong indications that the high level of interaction and discussion encouraged by iPads motivates learners better when compared to traditional lessons (Agostini & Di Biase 2012; Cox et al. 2003; Meyer 2013). Maher (2013) tied together different studies to communicate the possibilities of multiple learning pathways in the thousands of available iPad apps as an important explanation of motivated student learning. One gets the sense that this discussion would benefit from a more rigorous analysis of the constraints imposed on teaching with technology by diverse knowledge discourses (Bernstein [1975] 2005) and their implication for the effective use of iPad affordances. Lange and Meaney (2013) argue that strongly framed apps support early-stage learning, while strongly classified apps allow more expert learners to integrate knowledge and present it in a variety of formats.

Maher (2013) also stresses that the 'thousands of available iPad apps' also need to be regulated and used appropriately by the teacher in the classroom. Researchers such as Karsenti and Fievez (2013) and Brand and Kinash (2010) have shown that teachers generally recognise this and, on the positive side, tend to stress the knowledge *representational affordances* of iPads – see Churchill and Churchill (2008) for a discussion of these in relation to personal digital assistants more generally. There is a wider literature too that, without engaging the notion of affordance, emphasises the potential of iPad technology to represent knowledge in innovative and multimodal ways (e.g. Clark & Luckin

2013; McPherson 2009; Nikolopoulou 2007; Ntuli & Kyei-Blankson 2010). However, there is also evidence that teachers prefer the bigger screens of older devices like desktop computers or laptops when it comes to composing long texts or creating multimedia artefacts (Chinnery 2006; Pegrum, Howitt & Stripes 2013).

It should also be noted that there is contradictory literature about whether iPads can afford particular kinds of pedagogies. So Clarke and Abbott (2016) endorse the benefits of iPads in reinforcing traditional pedagogy, and Murray and Olcese (2011:48) regret that iPad applications are seldom 'anything more than a behaviourist or proto-cognitive theory of learning'. At another extreme, Cochrane, Narayan and Oldfield (2013) claim a close link between iPad capabilities and social constructivist pedagogy. Bente (2014) finds that the primary affordance of the iPad is to enable teachers to link the multiple artefacts of learning – pens, paper, books, PCs, whiteboards, etc. – in constructing the material culture of the classroom. Nguyen et al. (2014:8) conclude that there is a 'lack of innovative pedagogical guidelines' in the iPad affordances literature – probably correctly if one recognises our earlier injunction that pedagogical affordances are not pedagogies.

Table 6.1 represents the understanding of the technological and pedagogical affordances of the iPad, which has been suggested by the preceding discussions and by Drennan's (2018) research. When viewing it, it is important to keep in mind the principle that there is a distinction between affordances and their actualisation. The affordances are the potentials in the iPad itself for pedagogic actions with respect to a teacher's or learners' goals. The actualisation, as the action itself, is the actual configuration of pedagogic practices that make up any classroom (teaching and learning) episode. Thus, while affordances relate to potential actions and the educational outcomes they are intended to achieve, actualisation relates to specific actions that particular teachers or specific learners have taken. We move now to report on a study of the actualisation of some of these iPad affordances in a Johannesburg primary school that employs a Reggio Emilia curriculum.

Reggio Emilia: The documentation of visible learning

Against the background of the possible pedagogic affordances of iPads, the present ethnographic study sought to explore the use and affordances of iPads in the documentation of learning, by both a developing teacher and primary school learners, in a Reggio-inspired school. *Visible teaching and learning* is a key theoretical concept in the Reggio approach to learning, and its *documentation* is a key part of the systematic pedagogic strategy employed in such classrooms. The specific research problem tackled here is

TABLE 6.1: The capabilities, technological affordances and pedagogical affordances of iPads.

iPad capability	Technological affordance	Pedagogical affordance
Size	Portability	Polysynchronous learning – learning is ubiquitous, asynchronous, flexible
Long battery life	No need for a power cable	Mobility of teachers and learners, inside and outside of the classroom
Touch screen	Direct interface	Tap and swipe – decision-making, learners control their own decisions ('the click option')
Intuitive interface	• Quick and easy to learn • No mouse, no external keyboard or trackpad • Keys do not stick	• Teach with and through, not about, technology – operational-thinking • Team teaching and materials development
Multimedia capability	Make and playback audio and video recordings	Movie or audio recordings
Integrated images, audio and video resources	Access to worldwide resources	• Written or spoken comments • Authentic learning • Virtual stage or performance • Multimodal convergence • Sophisticated presentations • Multiple representations of knowledge • Digital textbooks • The teacher carries little home
Guided access	• Temporarily restrict to a single application • Choose which app features are available • Disable hardware buttons	• Stay on task • Learner focus or 'ownership' • Disable task-irrelevant screen areas • Prevent accidental gesture distractions
Applications	Seamless integration	Document and resource-sharing makes collaborative work easier
Apple TV	Share screen of one iPad	Learner construction of material – researching, producing, representing
Apple Classroom	Monitor and manage iPads	• The whole class can see peers' or teacher's work – text, audio, to the whole class • Only the teacher can see learners' work • The teacher sends or receives work through any application to or from individuals • The teacher provides corrections

Source: Adapted from Drennan and Moll (2018:125).

to establish how a general typology of iPad pedagogic affordances, such as that elucidated in Table 6.1, is actualised in this specific curriculum and pedagogic framework.

Reggio Emilia is a city in Italy, claimed to have 'the most innovative, high-quality, city-run, infant-toddler and pre-primary systems in the world' (Hewett 2001:95). The schools and the educational system associated with them were first established by Malaguzzi (1993a, 1993b, 1994) in the years after the Second World War, in the context of broad poverty alleviation and reconstruction efforts. More recently, Reggio pedagogy has been extended more generally across a number of primary schools. Hewett (2001) outlines ways in which learners are viewed in Reggio: firstly, as capable individuals with rights whose thinking should be taken seriously. Secondly, as individuals who have the ability to research what has been presented to them. Thirdly, as constructors of their own knowledge, meaning that they have the ability to create their own theories and understandings based on what is presented to them. Lastly, as social beings who construct knowledge by interacting with others and their environment. It is clear from these formulations that Malaguzzi was inspired by constructivist thinkers like Piaget and Vygotsky (Edwards 1995; Hewett 2001; Rinaldi 2001a) and progressive educators like John Dewey. He apparently joked that Dewey was more alive in the Reggio Emilia schools in Italy than in the United States of America (USA) (Edwards 1995:4). From Vygotsky, Malaguzzi took up the idea that learners' learning is situated in a sociocultural context and takes place in interrelationships, requiring the construction of an environment that allows for maximum movement, interdependence, and interaction' (Dahlberg & Moss 2001:6). And from Piaget, he adopted the concept of the active, thinking, constructing child. Edwards (1995:4), in her analysis of Malaguzzi's writings, suggests that the principle of 'cognitive conflict and disequilibrium in powering cognitive growth [...] was deeply internalized by Malaguzzi'.

Reggio values collaborative work 'among teachers, children and parents' (Treppanier-Street & Hong 2004:89) – Malaguzzi (1994) spoke of the importance of 'relationship' in teaching and learning. Teachers, learners and parents/guardians are viewed, as 'co-learners' and 'collaborators' (Hewett 2001:97) in the pedagogic process, in which they develop shared understandings of the learner's learning. In common Italian parlance, they all become *protagoniste*, characters in a community of 'gesture, language, mind, emotions, and interests' (Kennedy, cited in Edwards 1995:6; MacDonald 2007) or what Kashin (2016) refers to as a pedagogy of listening, observing and documenting learners' work. One of Malaguzzi's favourite metaphors was 'the hundred languages of the child', to refer to the multiple ways in which children are capable of speaking about and representing their experiences of the world and their learning. Teachers, too, are able and encouraged to reflect on their practices in these engagements (Hewett 2001).

Malaguzzi's most important pedagogical principle was that learning is the consequence of thinking, or more specifically, of thinking about and learning from one's actions on the world (Rinaldi 2001a; Ritchhart & Perkins 2008) – by the way, an indication of the influence of Piaget and Vygotsky on his ideas. The Reggio curriculum is constructed as a series of opportunities for thinking routines: Edwards (1995) describes this as pedagogic sequencing that poses resolvable but genuine problems or conflicts, inclines learners to take and coordinate multiple perspectives and makes learners think in structured ways that deepen both cognition and emotion. For Malaguzzi (1993b):

> [/]t is not an imposition on children or an artificial exercise to work with numbers, quantity, classification, dimensions, forms, change, or speed and space, because these explorations belong spontaneously to the everyday experiences of living, playing, negotiating, thinking, and speaking by children. (p. 45)

Such routines allow learners to grasp and systematise concepts and help them *make their thinking visible*. Visible thinking 'refers to any kind of observable representation that documents and supports the development of an individual's or group's ongoing thoughts, questions, reasons and reflections' (Tishman & Palme 2005:1). In Reggio, the learning process depends on learners documenting their own thinking and therefore making it visible to themselves and to their teachers and families in collaboration with them. It goes without saying that multimedia need to be used to document such visible learning – notes, audio and video recordings, photographs, examples of the learners' work that represent what they did and said, et cetera.

Malaguzzi conceived pedagogical documentation as (MacDonald 2007):

> [*A*] visible trace that captures what children did and said during interactions [...] a tool for continuous reflection while making the learning process visible to teachers, parents, and members of the community. (p. 232)

Documentation is variously described by Reggio proponents as creating a disposition toward rigorous, critical reflection (Rinaldi 2001a; Ritchhardt, Church & Morrison 2011; Seitz 2008) and as a 'process for making pedagogical (or other) work visible and subject to interpretation, dialogue, confrontation (argumentation) and understanding' (Dahlberg & Moss 2001:15–16). It is also particularly important that teachers document (make visible) their own learning (Rinaldi 2001b). Seitz (2008) argues that this is valuable in understanding the reasons behind the way they guide learners to collect visible evidence of their own learning. In the process of documenting learning, teachers receive the opportunity to reflect on their practices and to learn about their own learning as well.

We turn now to the possible affordances of ICTs in such pedagogic documentation. A careful literature search revealed only two specific sources related to the use of iPads in documenting visible learning in a Reggio classroom: firstly, a blog entry by Kashin (2016) containing very general ideas about the use of digital tablets for the purpose. This blog entry is useful in conceiving how a portfolio of digital ethnographic data, including audio and video recordings, notes, transcripts, photographs, slideshows, mind maps, computer-generated graphics, journals, charts and learners' artwork, can be stored and classified efficiently using technology such as the iPad. Secondly, there is a useful article by Parnell (2012) exploring how mobile phone and tablet technology can be used by teachers to document visible learning in their classrooms. Then there is literature on ICTs more generally in Reggio Emilia-inspired projects, including teacher education contexts. Treppanier-

Street, Hong and Bauer (2001) found, among other things, that it is easier to share learner's work with parents, that technology helps in revisiting topics covered and that such technology to document learning is advantageous because it is cost-effective and saves time for both teachers and learners. However, the work of Treppanier-Street and her colleagues tends to be about the technological rather than pedagogical affordances of ICTs in Reggio spaces. Finally, there is some literature on which to build regarding the training of teachers in the documentation of visible learning using tablets and other ICTs (Rosen & Jaruszewicz 2009; Treppanier-Street & Hong 2004). That, then, is the sparse literature related to the use of tablet technology in Reggio contexts.

Methodology

This research was conducted to understand the pedagogic integration of iPads into the new Reggio educational approach that had been adopted by a specific school. The study was thus not even constructed as a case study, but simply as a general qualitative study, as at that time this particular curriculum project was perhaps unique in the South African context. It also had a strong auto-ethnographic element in that it was a self-study by a teacher in her own classroom, seeking 'to describe and systematically analyse (graphy) personal experience (auto) in order to understand cultural experience' (Ellis, Adams & Bochner 2001:1). As Jerome Bruner indicates, such research combines characteristics of autobiography and ethnography: an author retroactively writes about past experiences that are assembled using hindsight (Bruner 1993).

Location and participants

The study design was set up in the classic mode of the teacher-as-participant-observer conducting a detailed ethnographic study of her own classroom (Erickson 1984, 1985). A generalist primary teacher (the first author), over a period of six weeks, investigated how iPads, and digital technologies in general, contribute to the documentation of visible teaching and learning for young learners.

The school that was selected for this study was obviously purposefully sampled. The participants were all Grade 7 learners at the school and all owned iPads that they were expected to use in school activities. There were 56 participants in total, 28 in each of the Design and Technology classes taught by the first author. Ethics clearance for the study was obtained after formal consent was obtained from the parents or guardians of each participant and formal assent from each of them themselves. Both parents and participants were fully informed of the purposes of the study in advance and generally

TABLE 6.2: The structural design unit in the school's Design and Technology curriculum.

Themes/topics	Design and Technology	Tuesday and Thursday classes
Theme/topic: Bridges	Lesson 1	• Recall forces affecting structural design • Types of bridges • Watch video on Tacoma bridge failure • Use 'think–puzzle–explore' thinking routine • Tacoma bridge failure information sheets
	Lesson 2	• Online research about the Tacoma bridge collapse • Discuss class list of ideas from previous lesson • Use 'headlines' thinking routines • Class discussion of headlines
	Lesson 3	• Recap reasons for Tacoma bridge collapse • Bridge design worksheet • Plan for building bridge model
	Lesson 4	• Building and documentation of bridge model
Theme/topic: Cities	Lesson 1	• Cities and their bridges – link to previous theme • Introduction to city planning • 'Question starts' routine – brainstorm city planning • Class discussion • History of cities worksheets
	Lesson 2	• Discuss history of cities • Explore land use of city of Johannesburg • Use 'explanation game' routine • Draw own plan of city
	Lesson 3	• Presentations of own city plan • Microsoft PowerPoint on city planning and class discussion • City planning video • Underdeveloped land use map
	Lesson 4	• Discussion on city planning • Design and plan city

responded with enthusiasm to the invitation to participate in it. The findings of the study were reported back to the school community.

Prior to the commencement of the period of the ethnographic study (i.e. data-collection), learners were introduced to the Design and Technology *structural design* unit, formulated in accordance with the national schools' *Curriculum and Assessment Policy Statement* for the subject Technology (Republic of South Africa 2011) – this unit is summarised in Table 6.2. The lessons were purposefully chosen and designed to encourage the use of *thinking routines* (see Figure 6.1) and to integrate iPads to document visible learning. It is important to note that both of the Grade 7 classes were exposed to the same prepared experiences and lessons. A 'lesson' focused on each topic was timetabled once a week; however, the learning activity associated with each took place over a whole week in various kinds of online, offline and asynchronous communication events using iPads. In a sense, classwork and homework 'blended' into each other in an ongoing learning process week by week. This is one of the virtues of the introduction of iPads, from a motivational point of view.

Data gathering and coding

A 'thick description' (Geertz 1973) of ongoing activities was produced in which iPads were used by learners to document their own learning. Such a methodology seeks to 'accurately describe observed social actions, by way of the researcher's understanding and clear description of the context under which the social actions took place' (Ponterotto 2006:543). Importantly, the teacher herself used an iPad to document her own learning about the use of such technology. A range of ethnographic data, including transcripts of classroom conversations, learner's work, photographs, classroom observation notes and *in situ* interviews, were gathered and then analysed by means of standard open and axial coding procedures (Corbin & Strauss 1998; Charmaz 2006). It is important to note that not all work carried out by the learners in these lessons was produced by iPads, but it was all documented by them using various tools and apps. These 'documentations' then became the foci for systematic classroom discussion on what had been learned. It is worth recalling the observation of Bente (2014), mentioned in the literature review that the primary affordance of the iPad may well be its representational ability to link the multiple artefacts of learning in constructing the material culture of the classroom.

The learners were also already generally familiar with the meaning and practices of thinking routines as an activity and learning process in the classroom and beyond. Broadly speaking, a thinking routine is a simple, specified or 'signposted' pattern of thinking that can be used repeatedly in relation to several different tasks. So it becomes procedurally familiar to learners. It uses the language of thinking – words like hypothesis, reason, evidence, possibility, imagination and perspective. Such routines 'fold' easily into learning in any discipline or subject area and have a public nature in ongoing collaborative interactions in a community of learners (like a 'class' at school) (Perkins n.d.:2; Ritchhart 2002). The prevailing thinking routines for any day, or any lesson, are always on display on a central bulletin board (Figure 6.1). So in the period of this study, the thinking routines styled as 'question start', 'explanation game', 'think–puzzle–explore' and 'headlines' were set out on various branches of the thinking tree. Of course, learners always photograph this with their iPads and include it in their displays and presentations.

Findings and data analysis

Most of the affordances of iPads in Table 6.1 were evident over the course of the ethnographic study. This chapter obviously cannot record them all but presents selected exemplars to illustrate how they were used to document visible thinking and encourage a CP in the classroom.

Source: Photograph taken by Nelisiwe Phakathi, exact location and date specified. Published with appropriate permission from Nelisiwe Phakathi.

FIGURE 6.1: Bulletin board dedicated to the thinking routines.

The *polysynchronous learning* encouraged by iPad use and interconnectivity was evident in the constant production and discussion by learners of documents and records related to the 'city planning' unit, in class, on the playground and in virtual communication throughout the week. One group, for example, was so invested in its work that one learner asked, 'can we work on our project during break – I mean, our brainstorming ideas?' Another is heard saying she has a tennis meeting at break, and the first replies, 'we can email you the work when we are done, and you can say if you like it or not'. iPad features such as size, long battery life and touch screen allowed for flexible learning. AirServer software was used to mirror the learners' screens to the smart board for all to see during class discussions. iPad capabilities such as touchscreen, intuitive interface and integrated audio and video made it possible for learners to enhance their presentation of work. Instead of drawing a mind map for their planning, learners opted to make use of apps like Popplet to plan their work (see Figure 6.2 and Figure 6.3).

The evidence of *controlled decision-making and operational thinking* (see Table 6.1) by learners was abundant. Generally, a 'question starts' thinking routine is used to commence a lesson. This routine, also called 'creative

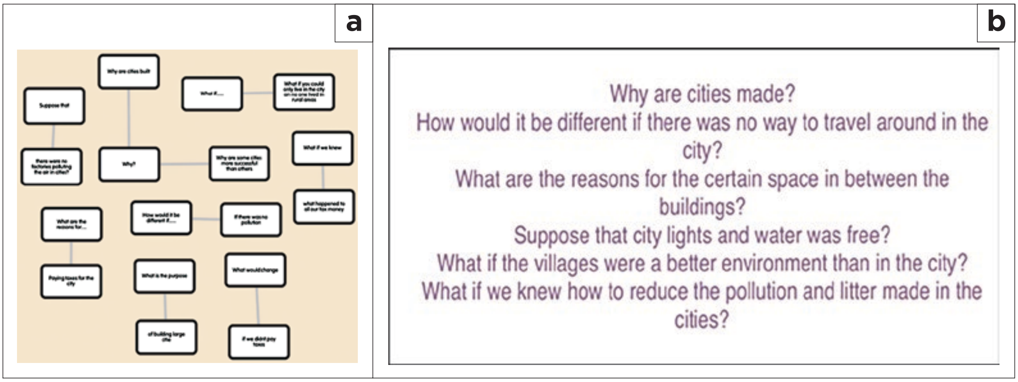


FIGURE 6.2: Learners' use of the Popplet app (a) and Keynote app (b) in the 'Question Starts' routine.

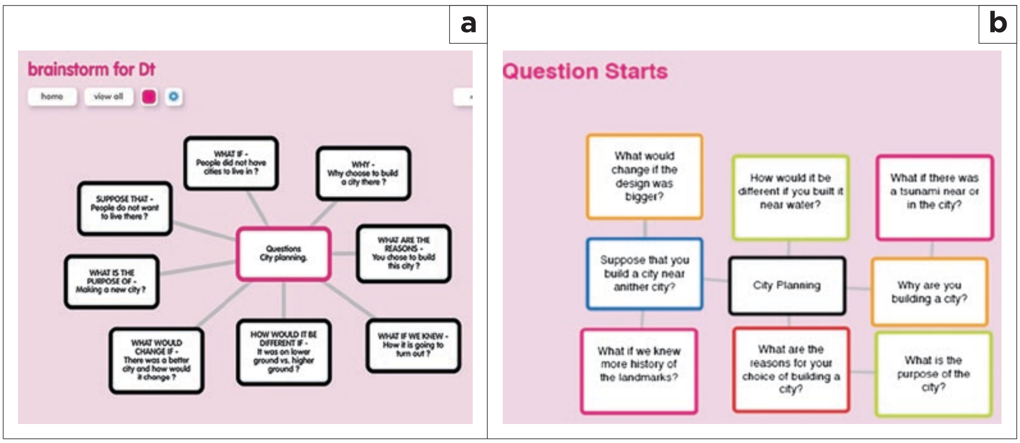


FIGURE 6.3: Learners' use of the Popplet app: (a) brainstorming and (b) questions posted.

questions' emerges from the discussion of questions as one of eight 'thinking moves' identified by (Ritchhart, Church & Morrison 2011). Using the affordances of the iPad in this routine establishes a sense of control over producing records of ideas from the start.

Learners generated questions in group discussions and mapped them on their iPads using any app or other means they chose. Figure 6.2 and Figure 6.3 are examples of work where learners made their thinking routines visible. They shared and discussed their responses with the whole class by mirroring the screens. In particular, common questions from different groups were noted and discussed. Learners' tasks were also printed and displayed on the interactive board at the end of the process. This allowed them to engage with the lesson material more effectively and helped learners create their own content. From the observations, as learners were given the freedom to use apps of their choice, they seemed to discuss their experiments with potential apps easily they might like to use. They were observed helping each other use the iPads for this purpose. Learners used a variety of apps to make their presentations and thus make learning visible using their own constructions.

This ease of representing ideas on their iPads meant that learners took responsibility for tasks and grew in confidence and independence. An example was when the teacher asked, 'What makes a good question about city planning?'. One learner answered, 'A good question is one that causes you to think hard before you record your answer'. Using thinking routines and having learners document and present their thinking was of great importance as it led to learners feeling valued.

The *multimedia representational affordances* of iPads (see Table 6.1) were realised continually in the work produced by learners in and beyond lessons. Learners used iPads to document their work, this helped them to think about the tasks the were working with. In all lessons, previous documentations were revisited to see if there were new developments from what was taught previously. Learners would make connections with what they have learned in continually building *linked* representations of their emerging knowledge in iPad hypertexts. One good example of this emerged from the '*explanation game*' thinking routine (look closely, name it, explain it, give reasons and generate alternatives) (Ritchhart, cited by Lynch 2016). Figure 6.4 contains some of the representations of the structure and appearance of cities using different software affordances. Learners also shared and discussed their ideas with the class, using presentation software in their iPads connected to a data projector and were thus given opportunities to review and analyse their peers' work (see Figure 6.5). Learners' presentations were thoughtful, and it was then easy for them to review their work as they carried the iPads with them wherever they went. Their work on this developed in multiple ways, using multiple apps, beyond the introductory engagement in class. This work was supported by an information sheet detailing the different city designs prepared

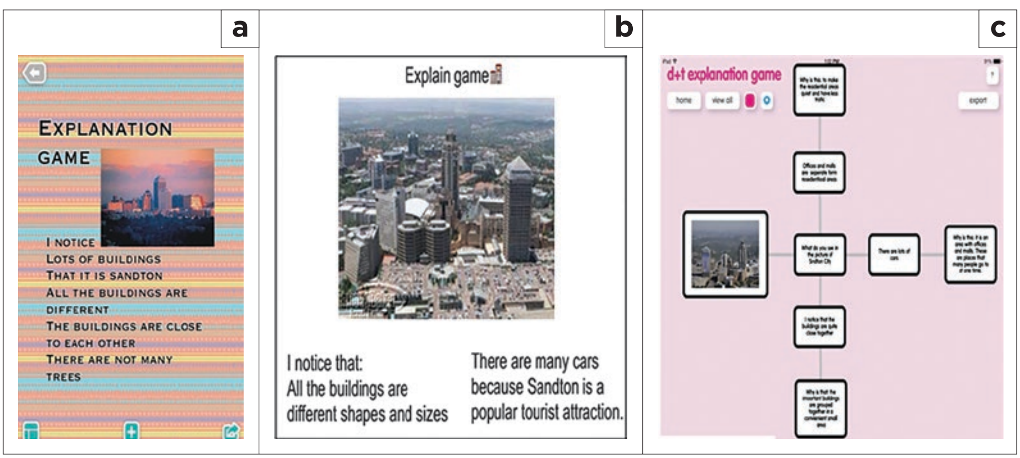
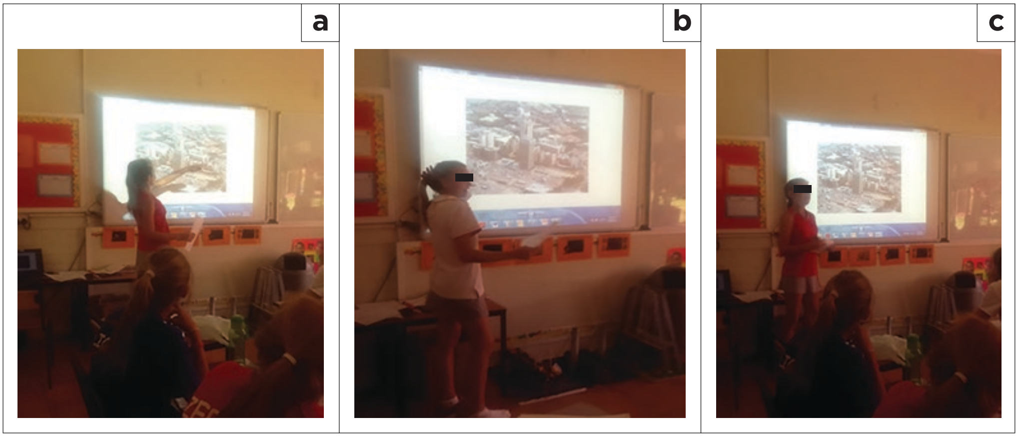


FIGURE 6.4: Learners' representations of the explanation game on the (a) Poster app, (b) Keynote app and (c) Popplet app.



Source: Photograph taken by Nelisiwe Phakathi, exact location and date specified. Published with appropriate permission from Nelisiwe Phakathi.

FIGURE 6.5: Whole class audio-visual presentations of work on city plans. Learners discussing their city in figures (a), (b) and (c).

by the teacher, which was shared on Dropbox. Drennan (2018:25) describes this use of multiple representational affordances as opportunities for learners to take on the role of 'teachers of content and technology' to their peers, and they were certainly actualised in this way in this classroom.

In the classroom discussion portrayed in Figure 6.5, for example, the teacher intervened to ask learners to identify the city – one learner said it was Sandton City. When asked to elaborate on her response, she said: 'The big building tells us that it is Sandton City, and it is in Gauteng'. The teacher asks other learners what they thought. Another pupil says, 'Sandton city is the name of a building; it is in the city of Johannesburg [...] The picture is Jozi (Johannesburg)!' The class discusses the difference between a province, city and suburb until the teacher is satisfied that the distinctions are consolidated for all the learners.

The teacher often facilitated pupil ownership of their learning by sending detailed task instructions and rubric guidelines to them by email or Dropbox, thus guiding learners to find relevant information themselves and, finally, ensuring they integrate pertinent aspects as they apply their newly acquired knowledge in the required format of their final presentation. One group thanked the teacher for helping them choose an effective app to collate information:

> 'Ms P, we used Keynote, I invited my group members and we worked on our presentation at the same time. It was even better than Microsoft PowerPoint as we could animate our work.' (Amanda, female, date unspecified)

There was evidence that this carefully mediated instruction developed the knowledge and skill of learners. Parents became aware of children working in more sophisticated, complex and collaborative ways. Students were more willing to discuss schoolwork with their parents.

The *document and resource sharing capabilities of iPads* were used extensively by the teacher and pupil participants in this study, as revealed by all the evidence discussed. The iPad's Dropbox application enabled pupils and teachers to easily share work with each other. For instance, labelled photos of famous bridges were circulated – Nelson Mandela Bridge in Johannesburg, Tower Bridge in London, Sydney Harbour Bridge, etc. Learners were guided to research city design: the teacher prepared a number of information and guideline documents, which were stored in a Dropbox for easy access. A large aerial photograph of Johannesburg was put up on the interactive board and enabled for interactive use on the iPads. Learners were also directed to carefully selected websites that had information pertaining to the topics to help them with their research. Learners also used the Apple Airdrop function on their iPads to share their work, be it photos or presentations; these were then used by the teacher. She would pick the relevant ones, print them and use them as displays on the bulletin boards. Finally, pupil responses to all the tasks which documented their thinking were also put in Dropbox as a guide. They always had to reference their sources properly, and the teacher paid particular attention to teaching them to reference websites. Drennan (2018) discusses 'teachers' triple agenda of content elaboration, academic argument, and digital citizenship'. She cites studies showing how teachers often discuss what proof or evidence reveals good thinking in their subjects and suggests that 'the iPad can change teachers' pedagogy by allowing them to add a third agenda to their teaching, good digital citizenship' (Drennan 2018:25). There were numerous examples in this study of how the teacher developed in this way.

When engaging with the theme of the structure of bridges, other good examples of multimedia representations were produced by learners. A still photograph of the Tacoma Bridge and a YouTube (2012) video of its collapse were viewed in class by learners on their iPads. They then used the 'think–puzzle–explore' routine, which allows learners 'to share what they think about the topic, identify questions that they puzzle about, and target directions to explore' (Ritchhart & Perkins 2008:57). In the course of an ongoing classroom discussion, the teacher asked learners to record their thoughts in a Microsoft Word table about what they understood about theÎ bridge, what puzzled them about it and what they would want to explore about the bridge collapse. One pupil put up her hand and said, 'it is impossible for a bridge to sway like that', and there were mumbles in the class. In no time there was a debate about the swaying of the bridge. Some asked, 'How could a bridge sway like that?' while others were asking, 'Is the base of the bridge not made out of tar?' The teacher instructed learners to reserve their questions and to use the think–puzzle–explore routine to categorise all the questions they have first. The learner's work (see two examples in Figure 6.6) was printed out and placed on a whiteboard for reference throughout the week. In subsequent 'homework' learners used this documentation to conduct research into why the bridge collapsed and to present their findings to the whole class.

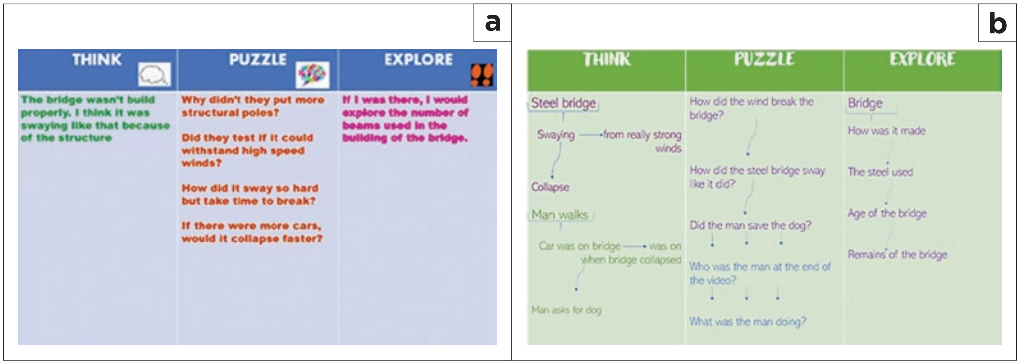


FIGURE 6.6: Examples of documentation produced during a (a) classroom discussion and (b) using Microsoft Word.

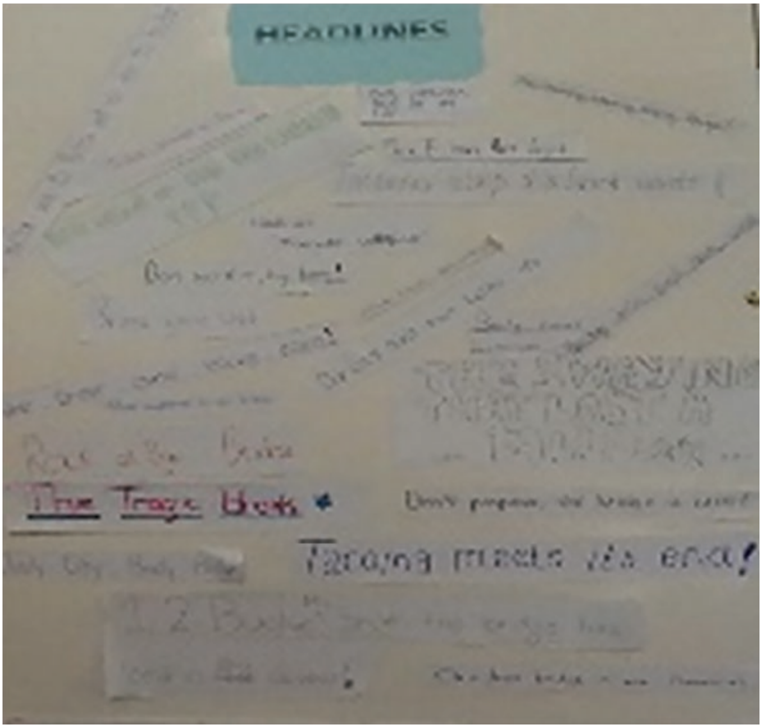
Another important illustration of the use of the iPad to document visible learning was the use of the 'headline' thinking routine, which uses 'uses newspaper headlines to capture the essence of an event, idea, concept, or topic' (Ritchhart & Perkins 2008:59). In this activity, the teacher and the class agreed that the most visible way to come up with and map relationships between newspaper headlines relating to the Tacoma bridge collapse was to do it on paper and organise them on a wall chart (here the affordances of 'old' technology trumped that of the iPad!). But of course, iPads were used to photograph the headlines that were produced and make the learning available for future discussions and tasks (Figure 6.7).

All these examples of multiple forms of presentation and representation together provide us with a strong sense of the affordances of iPads in the documentation of visible learning in this classroom.

The manner in which the teacher *guided access to and focus on salient ideas* in order to ensure a focus on the learning task (Table 6.1) was an important part of how learning was made visible by iPad affordances. Classroom tasks and discussions were guided using *thinking routines*. Learners used their different apps to record and share these routines in real time. What stood out was the way in which learners worked towards shared common ideas; they listened to the teacher and to others' ideas without interrupting. This is an important gesture in the Reggio approach. The teacher worked together with learners in this situation so as to facilitate this focused, collaborative construction of knowledge.

Discussion

The results show that iPads afford both the teacher and learners with complex ways in which they can document learning. At a theoretical level, the study suggests that iPad affordances add a range of previously unrealised



Source: Photograph taken by Nelisiwe Phakathi, exact location and date specified. Published with appropriate permission from Nelisiwe Phakathi.

FIGURE 6.7: The mapping on a wallchart of possible newspaper headlines.

representational and learning possibilities into a primary classroom. The implications for teacher education are explored in relation to a detailed model, developed out of the Drennan and Moll (2018) framework, of the affordances of iPads in documenting *visible learning*. The use of the technology in this way seems to create the hitherto unrealised possibility of continuity between the training of teachers in recognising their own teaching and learning and the recognition and assessment of learning by young children in their classrooms.

As indicated earlier, the Reggio tradition encourages the teacher to engage learners and parents in discussing the learners' learning. In Malaguzzi's (1993a:10) words, these 'relationships are the fundamental, organizing strategy of our education system'. However, the circumstances regarding frequent, ongoing dialogue with parents at this school are quite different to the postwar Reggio Emilia community context, where schools bridged into the local community and *vice versa* on a daily basis (Edwards 1995). Here, parents are able to engage *in* the school less frequently and often only 'after hours'. This requires that the documentation of learner's work is systematic and accessible, so that the sense

FIGURE 6.8: The teacher's documentation of her own (a) 'visible learning' and (b) learner's quiz results on the Socrative app.

of participation can be realised when parents do come to visit the classes to see what their children have been doing. The principle of 'relationship' is also encouraged among teachers, so that other colleagues visit each other's classes to ask learners about their work. This practice was particularly emphasised during this research project. Therefore, the various documentations produced and selected by the teacher had to be in line with this school ethos and had to boost learners' confidence. The iPad capabilities made this easy to do. Generally, teachers in this school are expected to integrate technology in their everyday teaching. The teacher in this study learned to use her iPad to record her own practices and interactions with learners.

The teacher realised this learning in presentations to colleagues during staff meetings, showing the progression of the lessons and the integration of iPads in her practice. In these presentations, she tried to 'practise what she preached' by showing how she could use iPad capabilities to make visible her own learning and to reflect on her own teaching and learning. Figure 6.8 contains two examples of how she communicated her lesson assessment strategies in the unit using the Microsoft PowerPoint and Socrative apps, respectively.

■ Conclusion

From within teacher education, there is an important literature which conceives of *visible pedagogy* as the best means to instil 'the ability to make wise educational judgements' in our students (Murris & Verbeek 2014; see also Phillips & Bredekamp 1998). Regarding the use of thinking routines in the education of teachers, they seem to offer a broad and flexible framework of reflective teaching strategies to enrich classroom teaching in content areas and foster education students' intellectual development at the same time (see Perkins, Ritchhart & Tishman 2009:5). While not implying that the Reggio approach is necessarily the way to go in HE, its advocates do suggest that pedagogic documentation offers a conception of how teachers are able to reflect on and improve their own practices (Hewett 2001; Rinaldi 2001a) and thus that it has implications for teacher education. It is important to note that the pedagogy associated with thinking routines provides for strong framing of the learning process (see Bernstein [1975] 2005), both in the way that the topics are sequenced and the way that the teacher mediates them. This is not the loose sense of children as 'free-ranging problem solvers who construct their own learning pathways [...] when left to their *own devices*', a notion often mistakenly attributed to Piaget (Moll 2002:17–18; emphasis added to highlight the pun in the context of this chapter).

Based on what was discovered in this research project, we would concur with the sentiment, that the systematic use of *thinking routines* and their *visible documentation* provides an important methodology that teacher educators might train their students to use and indeed use themselves in their own teacher education strategies. The strength of this kind of approach is that it would require emerging teachers to reflect on their own learning and teaching *in relation to the way that the children they work with think about their own learning*. There is a seamless relationship between the documentation of L&T at three levels in the *making thinking visible* strategy: by learners to document their own learning, by a teacher to document and understand her own classroom practice and by teacher educators as a strategy to train teachers in a systematised classroom pedagogy for young children.

One major finding of the study reported on here is that iPads offer a considerable range of affordances that could be used productively by student-teachers to document and enhance their work and in particular to make it visible for critical feedback from their lecturers in the ITE learning environment. The mobility and ease of operation of the iPad means it can readily be carried to schools and afford ease of use in classrooms while teaching. Its representational capacities afford access to multiple knowledge resources quickly and easily, literally at the tap of a button. It enables strongly guided remote mediation from lecturers when students are away from the university (or in current lockdown mode). It also encourages student-teachers to access, create and share resources for teaching among themselves and so build a sense of belonging to a professional community over the course of their training. Above all else, it tends not to 'let the technological tail wag the pedagogic dog', when used in ways that are illustrated. The model of the pedagogical affordances of iPads originally developed by Drennan (2018), described by Drennan and Moll (2018) and adapted here for use in a Reggio-inspired primary school classroom (Table 6.1) seems that it will provide a useful theoretical understanding for student-teachers and teacher educators as (and if) they adopt iPads in their work.

Chapter 7

A constructionist approach of ICTs in learning and assessment: Students' perspectives

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Abstract[12]

With the growing demand for 21st-century skills and the fast development of information and communications technology (ICT), learning facilitators are challenged with the transition from face-to-face (f2f) to online learning. To address this challenge, a constructionist approach to learning and assessment is used to promote dynamic teaching methods and flexible, accessible learning opportunities for their distinct environments. Twenty-nine students enrolled

12. Sections of this chapter represent a substantial reworking of Van Wyk (2020:102–113).

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for a postgraduate certificate in Higher Education (PGCHE) in South Africa and completed a module in computers and e-learning. The content of this module exposed students to a range of different ICT teaching and learning tools, applications, software and pedagogies needed to facilitate in an online environment. The assessment was conducted in several forms to include facilitator assessment, self-assessment and peer assessment. In this qualitative research study, a survey and student reflections were used to collect data. The study reveals that this unfamiliar approach of the student as a discoverer and a maker is slowly accepted as knowledge is constructed and reconstructed through self-directed exploration. The study confirms that the six dimensions found in the conceptual framework collectively enhance the student experience. The use of ICT tools coupled with the constructionist approach to learning and assessment allows students to learn from assessment and learn for assessment. Skills such as critical thinking, collaboration, creativity and communication are developed and evident.

■ Introduction

In a post-industrial society, where advancements in ICT have become the change agent for human activities (Birenbaum 2000), it goes without doubt that it is not just the attributes of the technology that influence learning but the different possibilities and learning opportunities that it offers. The product of multiple factors that is a synergy of effective, efficient and engaging learning (Khan 2001) is required. It is no longer sufficient to question how we learn but rather how we learn effectively and efficiently (Spector & Merrill 2008). Research has established that authentic, student-centred assessment plays a crucial role in enhancing deep learning (Cocciolo 2011; Conley & Darling 2013; McEachen, Fullan & Quinn 2017). The use of ICT has also proven to play a role in creating self-directed, collaborative, creative learning environments independent of space and time (Fu 2013). A learning theory that collectively aims to achieve this conglomeration of the benefits of situated learning, authentic and student-centred assessment, self-directed learning, collaboration and creativity is *constructionism*. Following an extension of the 'maker movement', Papert developed constructionism, where students construct knowledge by interacting with themselves and others and creating and sharing artefacts (Papert & Harel 1991; Rosenfeld et al. 2019).

In this study, the students are all adults who have already completed an undergraduate qualification. Owing to their diverse career backgrounds, students find themselves in positions where they are unsure about how to complete tasks and naturally seek help from their peers. They negotiate, collaborate, support and advise on topics to teach others what they know and help others learn. To capitalise on this, a constructionist approach to learning and assessment was investigated. Because students in this study are not used to a constructionist approach, online learning was supplemented with contact sessions, thus forming a blended learning environment. Blended learning supports ICTs in higher education institutions (HEIs) as it is efficient, interactive, accessible and flexible and offers a varied learning experience (Bozzo 2012; Falchikov & Goldfinch 2000; Khan et al. 2012).

This study aims to understand and evaluate the experiences of students as they complete an ICT-rich module that is presented using a constructionist approach. Their experiences of this approach with regard to learning and assessment shape their perspectives on constructionism as a learning theory. Therefore, understanding the students' perspectives of an ICT-enriched constructionist approach to learning and assessment is central to this study.

■ The role of information and communication technology in constructionism

The role of ICT in education has been growing exponentially over the last decade with the inclusion of interactive whiteboards, smartphones, flipped classrooms, virtual learning environments, educational computer games, et cetera (Learning Portal 2019; Livingstone 2012). In addition, personalised learning received increased support from researchers as the role of the teacher and the student changed. This change in roles resulted in an emerging student-centred approach, where flexible learning environments, innovation in terms of the use of ICT and pedagogy are researched (Ignatova, Dagienė & Kubilinskienė 2015). The theory of constructionism encapsulates elements of a global mindset and a digital culture.

Constructionism by Seymour Papert should not be confused with Jean Piaget's constructivism, which is a related learning theory (Resnick 1998). While both constructionism and constructivism advocate that knowledge is built by the learner, constructionism stresses the idea of building a tangible knowledge artefact that can be shared through the use of ICTs. Resnick (1998) claimed that the designing of activities encourages students to be involved, share interdisciplinary knowledge, think in a variety of ways and reflect while socially involved with others (Walton, Childs & Jugo 2019). The use of ICT in constructionism enables students to share knowledge, removing the boundaries of place and time. The role of the teacher changes to a facilitator and reviewer (Parmaxi et al. 2013).

Through this learning journey, students acquire new knowledge and skills, such as information literacy and technology literacy, through active engagement and incidental learning. Constructionists argue that students effectively construct knowledge when they have the opportunities to create, make and choose things they are interested in (Tanghanakanond, Pitiyanuwat & Archwamety 2006). Cocciolo (2011:13) found that 'the more experience gained doing something, the greater the confidence'. There is a direct correlation between confidence and experience gained as a student's self-efficacy changes.

Constructionism allows students to learn through social skill development. Papert (1993) claims that students show, discuss, examine and reflect collaboratively on the cognitive products or artefacts that they create. This allows them to develop in terms of content, social skills and thinking processes (Stager 2001). This constructionist pedagogical approach enables students to solve problems situated in meaningful activities and to develop skills, confidence and overall understanding (Cocciolo 2011). Constructionist approaches can be attained and are supported by blended learning environments. The use of ICTs in constructionism merges online learning and traditional classroom approaches.

Constructionist assessment

In this ICT-rich environment, following constructionist approaches, assessment is often carried out as part of the learning process. Herrington, Oliver and Reeves (2003) confirmed that authentic activities are seamlessly integrated with an assessment that reflects a real-world assessment. Assessment is regarded as one of the major tools in teaching and learning (Khan et al. 2012). Cole et al. (2000) indicate that traditional testing options, such as short answers, multiple-choice and true-false, are not suitable for constructionist assessment. Testing needs to enable students to demonstrate what they have learned multidimensionally (Tanghanakanond et al. 2006).

Authentic assessment activities reflect multiple performances and growth. Individual abilities are demonstrated through the progress of created products and artefacts. The involvement of students in assessment has increased across the spectrum (Falchikov & Goldfinch 2000). This takes the form of self-assessment and peer assessment. During self-assessment, students make judgements and inferences on their own work, whereas with peer assessment, they make judgement and inferences on the work of their peers. Rubrics are imperative to set a standard against which self-assessment and peer assessment can be scored (Allen & Tanner 2006). As peer assessment involves active learning and the joint construction of knowledge through discourse, it is seen as a manifestation of constructionism. Peer assessment often provides useful and detailed feedback that has formative benefits to improve students' learning. Teachers that fear the reliability and validity of peer assessment often deprive students of its many benefits. Although marks are not a valid indicator of achievement, teachers' main concern is with the agreement between their marks and those that are given by peers (Falchikov & Goldfinch 2000). In some instances, a poor or lacking understanding of criteria can lead to inaccurate marking.

To fully grasp the students' perspectives of this module that was designed based on constructionist principles, the LearnCube conceptual framework (Haw et al. 2015) was used. In both this module and the LearnCube, the function of ICT and the value of assessment are key.

E-LearnCube framework

In most cases, a conceptual framework is a researcher's own model that attempts to explain the relationship between the variables in the study. Alternatively, as in the case of this study, it could also be an adaptation of a model to suit the research purpose (Adom, Hussein & Agyem 2018). When researching ICT use and e-learning frameworks, one tends to look at how ICT was accepted (Davis 1989), adopted (Lin 2003) or integrated (TIM 2019). This study not only focused on the use of ICT but also the experience of the students towards the design of the module, authentic assessment activities, personalised learning, the learning environment and the changed role of the student and teacher.

Researchers found several factors relating to both the technology and the learning environment to consider when investigating student perspectives in an e-learning module (Barbera, Clara & Linder-Vanberschot 2013; Blackmon & Major 2012; Gopal, Singh & Aggarwal 2021). Thus, in researching possible e-learning frameworks suitable for ICT use, both factors, namely ICT use and student experience, that contribute to successful e-learning implementation were considered, as the students in the study would need to understand the design and development of content with technology.

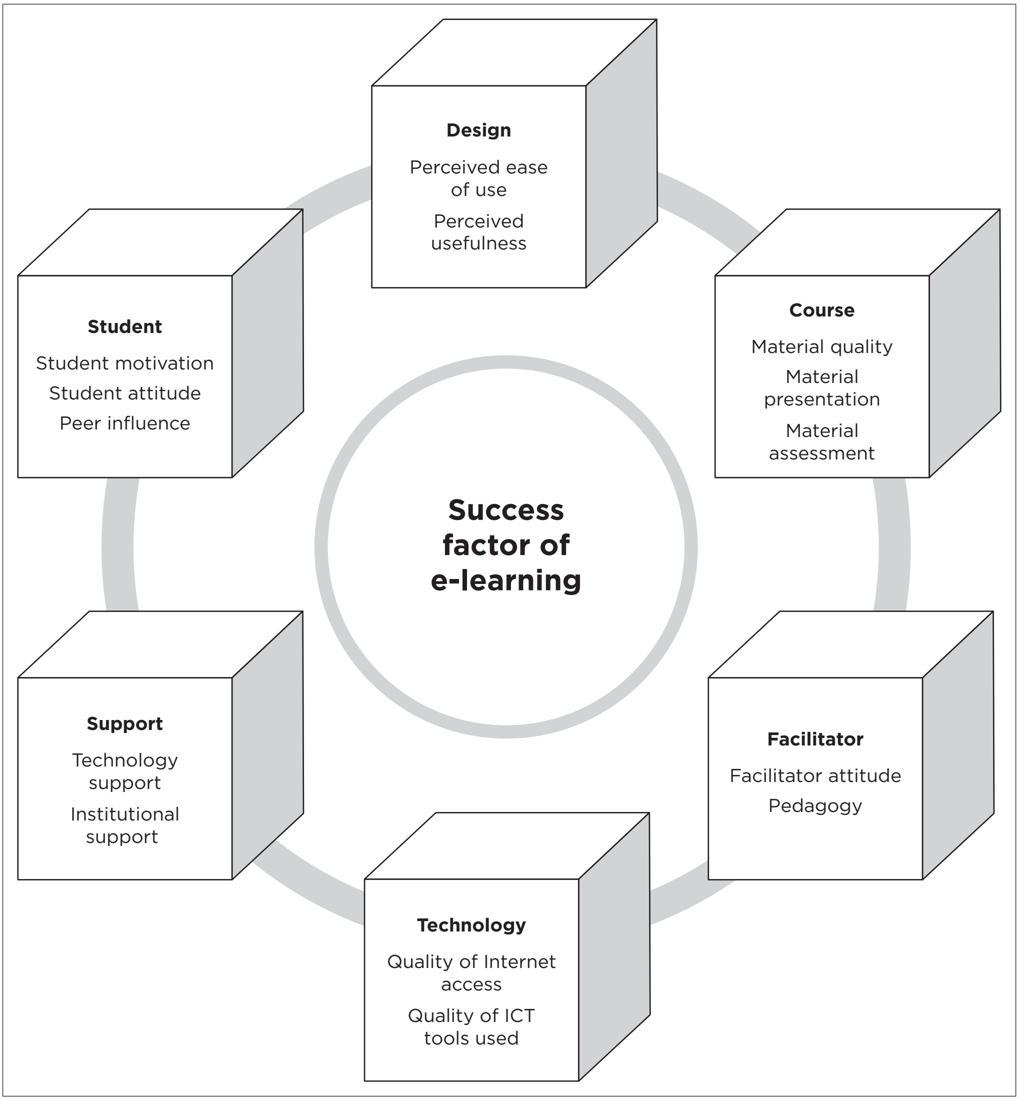
Khan (2001) proposed the first e-learning framework and highlighted eight components for successful e-learning. These eight components include the institutional, pedagogical and technological dimensions, as well as interface design, the evaluation of the learner assessment and the learning system, management, support and ethical considerations. However, in 2008, Sun, Tsai, Finger, Chen and Yeh simplified the framework and proposed six components for successful e-learning. Not only did they identify these components as learners, instructors, courses, technology, design and environment, but also they indicated what the critical factors are that contribute to learner satisfaction (Sun et al. 2008). Haw et al. (2015) refined Sun et al.'s (2008) work and drew on the work of Khan (2001) to identify the LearnCube, which consists of six critical success factors, each component contributing to the success of e-learning. The six critical success factors for e-learning are *design*, *course*, *teacher*, *technology*, *support* and *student*. Within the six factors are 17 attributes that are closely related (Haw et al. 2015). These dimensions are suitable for this study as it provides a holistic outlook on the design and development of e-learning content for learning and assessment. Therefore, this study draws from the conceptual

Source: Haw et al. (2015).

FIGURE 7.1: Differences between the original LearnCube and adapted e-LearnCube.

framework (see Figure 7.1) of Haw et al. (2015). However, the factors do somewhat differ for this study because of the context (HE), and therefore the model (Figure 7.1) has been adapted to form a new conceptual framework that framed this study (Figure 7.2).

As indicated in Figure 7.1, the quality of the content was removed from '*Design*' and combined with the material selection of '*Course*' into a new item called '*Material quality*' under '*Course*'. The '*Teacher*' component of Haw et al.'s model was renamed to '*Facilitator*' to fit the blended learning HE



Source: Haw et al. (2015).
Key: ICT, information and communication technology.
FIGURE 7.2: Adapted e-LearnCube.

environment, and the 'Peer' influence was removed as it is already part of '*Student*'. Under '*Technology*', the mentioning of YouTube and online forums was combined into '*Quality of ICT tools used*'. The original '*Support*' referred to '*Management and government support and resources*' and this was changed to '*Technological support*' and '*Institutional support*'. The reason for this change was that the focus was on the student perspective and only the support that they received from the institution was recorded. No changes were made to '*Student*' (Haw et al. 2015).

The design component mainly refers to how easy and useful the students find the access, flow, structuring and navigation of the course (Davis 1989). Structuring of the course also includes whether the content is easily digestible or chunked (Manning et al. 2021). Closely linked to the design is the course component. The content component relates to how the students experience the course in terms of the relevance of the content, flexibility and instructions and whether they feel comfortable engaging with the work (Haw et al. 2015). Another pivotal part of the LearnCube is the teacher's presence. The attitude of the teacher and how they teach, assess and provide feedback to students contribute to the full experience of the student (Freeman, Wright & Lindqvist 2010). Feedback is many times provided through rubrics. A rubric is not just a grading tool but is also used to provide feedback and improve course design (Ragupathi & Lee 2020). Technology, on the other hand, is the vehicle that is used to deliver content and create opportunities for engagement. The student's experience with the technology might either enhance or cloud the overall student perspective of a course (D'Angelo 2018). For many students, their first attempt at learning and assessment in an online environment can be traumatic, and therefore support from all spheres, such as technical support, facilitator support, institutional support or government support is crucial (Bates 2014). Lastly, student attitudes and motivation have an impact on both the experience and the success in online courses. However, experiences can be influenced by peers either positively or negatively (Haw et al. 2015).

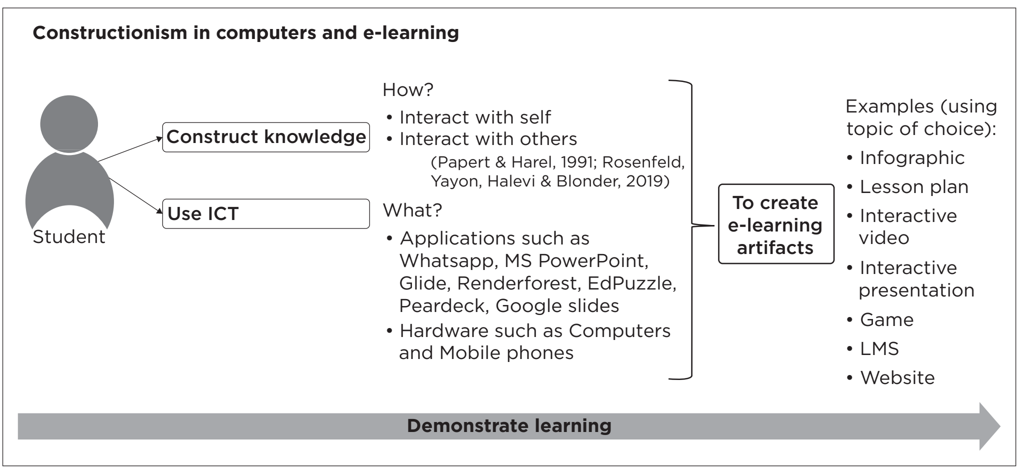
In light of this background, survey questions were developed and aligned to the adapted theoretical framework of Haw et al. (2015). For example, 'how did you experience the design of this module?', 'how did the quality of Internet access affect your experience and participation in this course?' or 'how has the influence of your peers influenced your participation in activities? Elaborate on your answer?' relate to the design, technology and student dimensions. Each dimension highlights aspects of the student's perspective on ICT use and the constructionist approach to learning and assessment.

■ Methodology

As students were applying what they learned in their authentic learning environments, this study lies within the interpretivist paradigm and follows a qualitative case study approach (Stake 1995). Twenty-nine adult students completed a module on computers and e-learning. This module was part of a PGCHE. The students were from different disciplines but all in roles that involved some form of blended or online teaching and facilitation. It was therefore imperative that the students learned how to design and develop content using technology and were able to present this content using modern teaching methods to promote 21st-century skills and ICT adoption in their work environments.

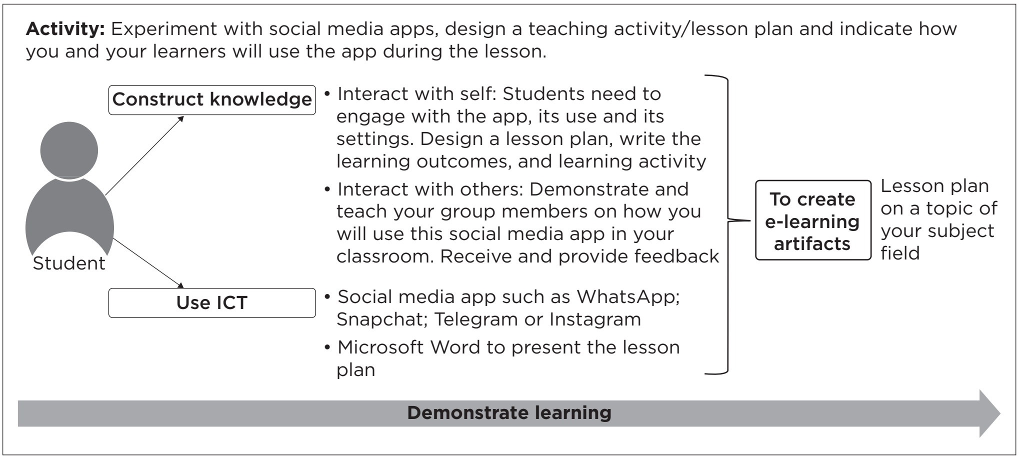
The module ran over one semester and followed a blended approach. The students attended four contact sessions with smaller online tasks between the sessions and a summative oral assessment. A constructionist approach was used to design the activities to ensure self-directed learning and assessment that improves metacognition through social interactions. The role of the facilitator was to guide students through the module. Students needed to read recommended learning material before the class and then start the class with a quiz based on the reading material. Thereafter, the activities of the week were discussed, where students had an opportunity to ask questions and discuss their experiences of completing the activities and showcase their artefacts. They can then start working on the activities from the preceding weeks in class. During the two weeks before the next class, students can communicate with the facilitators via email. In Figure 7.3, an illustration is given of how constructionism is used throughout the duration of this module under investigation.

As students are learning how to use ICT tools to create e-learning content, each activity has a different ICT tool assigned to it. It is important to note that only free online tools were used. For example, when the topic is 'Apps for teaching with technology', students need to try out social media app tools, animated videos and infographics. These tools were selected because they are visual multimedia tools and provide basic functions to create e-learning content that can be distributed on platforms the students are used to. Therefore, the content of this module exposed students to a range of different teaching and learning ICT tools (see Figure 7.5) needed to facilitate in an online or blended environment. A summary of how constructionism is evident in one of the assessment activities is shown in Figure 7.4.



Source: Image generated by Mari van Wyk, published with appropriate permission provided by Mari van Wyk.
Key: ICT, information and communication technology.

FIGURE 7.3: Constructionism in the Computers and e-Learning module.



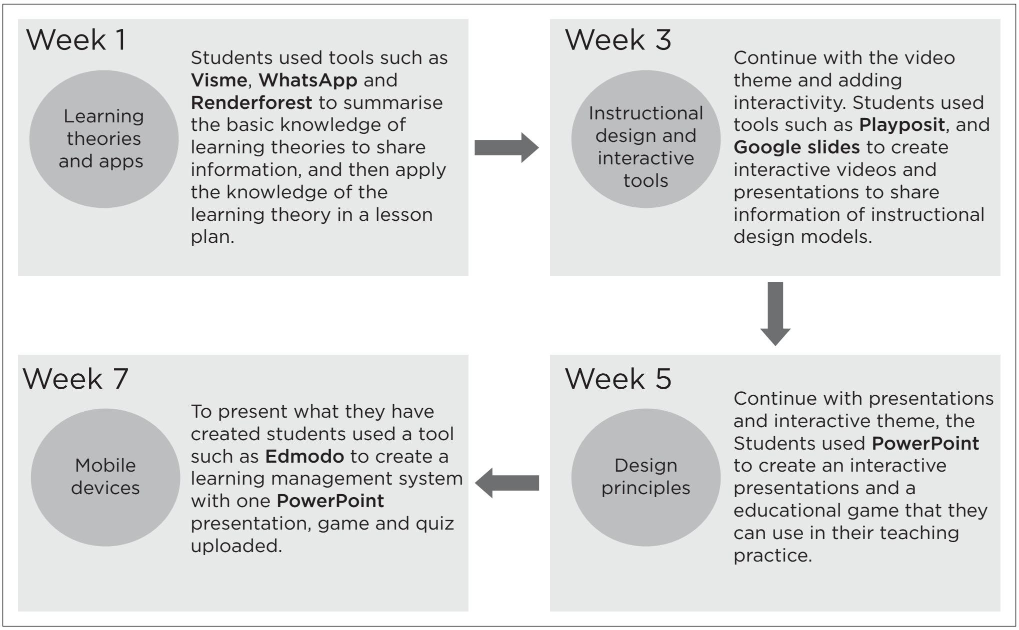
Source: Image generated by Mari van Wyk, published with appropriate permission provided by Mari van Wyk.
Key: ICT, information and communication technology.
FIGURE 7.4: Constructionism in the Week 1 activity.

As indicated in Figure 7.4, students were asked to choose a topic and engage with the topic that they were familiar with in a self-directed manner. Then they needed to choose an appropriate ICT tool from the examples given and create an artefact (which they would be able to use in their training environment). This artefact would then be demonstrated to their peers not only to receive feedback but also to see and learn from what their peers had tried. After the feedback was taken into consideration, these artefacts were then assessed (see Figure 7A-1 for an example of the rubric). For examples of tools used during the activities, see Figure 7.5.

The assessment was conducted in several forms to include facilitator assessment (social media lesson plan using the rubric provided, see Figure 7A-1), self-assessment (using rubrics to create, for example, an interactive Microsoft PowerPoint slideshow) and peer assessment (watch, engage in and mark interactive peer games). Activities such as using social media applications for

	1 – Needs major improvement	2 – Satisfactory	3 – Excellent	Score
Learning outcomes	Learning outcomes are not stated. Students cannot determine what they should know or be able to do as a result of the learning intervention.	Learning outcomes are stated but have minor errors. With some explanation, students can determine what they should know or be able to do as a result of the learning intervention.	Learning outcomes are clearly stated. Students can easily determine what they should know or be able to do as a result of the learning intervention.	

Source: Author's own work.
FIGURE 7A-1: The marking criteria of the assignment.



Source: Image generated by Mari van Wyk, published with appropriate permission provided by Mari van Wyk.

FIGURE 7.5: Examples of tools used (one example each).

teaching and learning, mobile learning management systems (LMSs), websites and animated videos were structured to allow for online participation and f2f participation.

At the end of every contact session, students were asked to write a reflection regarding their experiences of the f2f session and the online aspect of the module. Reflections are important to determine what you have learned and to make connections with other activities or modules (Back 2019). Guiding questions (see Figure 7A-2) were used to probe experiences and perceptions. At the end of the module, students completed a survey reflecting on their experience of the entire module. This survey was designed to align with the e-LearnCube framework (see Figure 7.2). The data were extracted from the LMS and sorted using Microsoft Excel. A deductive content analysis (Elo & Kyngäs 2008) was used to analyse the survey data. The researchers started the analysis with the research question in mind and read through the responses to identify and highlight common keywords, recurring patterns and related themes that relate to the components of the e-LearnCube (Haw et al. 2015). To triangulate the data, we compared these responses with the weekly reflections. While the weekly reflections intended to reveal the growth and development of ICT and 21st-century skills on a weekly basis, the survey data were intended to confirm the student experience as they described their learning journey and their experiences of the constructionist approach to teaching and learning. After the participants had given written consent, data

Consider the following questions as you think about your learning journey over the past two weeks, since starting with Week 1.

(1) What were some of the most interesting discoveries you made while working on this week's activities? About the activities? About yourself? About others?

(2) What were some of my most challenging moments and what made them so?

(3) What were some of my most powerful learning moments and what made them so?

(4) Assuming we were learning about the same topic, and you could decide how you would like to provide evidence of your learning, how would you have preferred to demonstrate learning achievement and why?

Source: Author's own work.

FIGURE 7A-2: Questionnaire about the student learning journey.

were collected electronically and are currently stored on a password-protected device. To ensure anonymity, the survey was conducted anonymously and pseudonym PX was used for the survey data. For the reflection data, the pseudonym RX was used.

Student perspectives on learning and assessment

After analysing all the survey responses, the data that related to the six components of the e-LearnCube were identified and highlighted, irrespective of what the responses were. These components are design, course, facilitator, technology, support and student (Figure 7.2), and the findings were discussed under these predetermined themes. For example, if the student mentioned that *the technology was difficult to use* under the question, 'How did you experience the design of this module?', the comment would be placed under technology and not design. Keywords were identified and used to analyse the student perspectives of learning and assessment through constructionism. The use of ICTs featured prominently in the module and impacted the students' perceptions.

Design

The students expressed an overall positive experience of the design of the course and expressed their appreciation for the constructionist approach to learning and assessment. They acknowledged the bite-size learning in the form of small assessments that promoted not only multiple learning opportunities but also formed a building block to the final assessment. When exposed to challenging activities and seeing the work of their peers, their creativity was instigated, and they found the practicality of the work appropriate and relevant (Manning et al. 2021). This modelling teaching approach contributed to their perceived usefulness and perceived ease of use of ICTs: 'practising what you preach was very encouraging, as you facilitated in the way in which you were advocating' (P27, age unspecified, date unspecified).

When they accomplished their tasks, they felt empowered and amazed with their ability to complete the assessment activities, and they were able to actively see the learning that was occurring. P2 specifically mentioned that social media platform tools could be used in the classroom. They were able to use the skills from one assessment activity to complete the next assessment activity and could consult with their peers if they were unsure about any task (P26). As one participant mentioned, '[...] you get to create your own applications in your own style' (P14, age unspecified, date unspecified).

The selection of ICT tools was carefully aligned to each activity and enabled the students to create the intended artefacts (see Figure 7.5). The students expressed their gratitude for the value the course added to their teaching and presentation skills. They specifically found the variety of ICT tools useful and easy to use. As P18 mentioned:

> '[*M*]ost of the tools that I was introduced to are important for delivering the lesson and I learned that e-learning is an easy way to deliver the lesson to make it more engaging and interactive.' (P18, age unspecified, date unspecified)

R5 added:

> '[*H*]ow easy it is to combine different applications or programmes with each other. Using one programme to create an interactive video and linking it to a Prezi presentation, for example, is very easy and it adds creativity to the content design.' (R5, age unspecified, date unspecified)

☐ Course

The course materials were structured around the use of predetermined e-learning tools to ensure constructionist learning and assessment take place (see Figure 7.4 and Figure 7.5). This was intended to create an experience focusing on design principles and the use of ICT. The presentation of this constructionist blended learning module was overwhelmingly positive for the students. They mentioned that they could work at their own pace and do the research they needed to (P13), that they learned a great deal from working with their peers (P10) and that they enjoyed creating videos and using the technology (P5). Although participants experienced the constructionist approach (being the discoverer, designer and maker [Cocciolo 2011]) as different from what they were accustomed to (traditional teaching), they did mention that after their initial confusion, they did adapt and were able to complete the course with a sense of accomplishment. This constructionist approach relies on students interacting with themselves and peers and creating artefacts, which was not only a different experience but also a challenge for them to think and do things differently. As P1 mentioned: 'I learned a lot of things that will make me a very different facilitator from the rest in my industry' (P1, age unspecified, date unspecified).

In addition, participants experienced the classes as engaging and interactive and took comfort in knowing that all they needed to know was provided in the instructions. The activities were well thought-through, and the students experienced the ICT tools as beneficial to their learning and easy to understand (P2, P3). For example, R1 mentioned:

> 'Creating the infographic was a perfect way of demonstrating my learning achievement. By creating an infographic and sharing it with the class, results in you having to apply the learning theory in practice as well. Thus, you provide practical and theoretical evidence.' (R1, age unspecified, date unspecified)

R3 also added that the Mentimeter app (quiz or student response system) is 'awesome and so easy to use, and it can be used like a game show in class. I am so excited to use this in my teaching'. This remark indicated the excitement and contribution that these apps made to their teaching practices.

Students made special mention of the advantages of rubrics that were provided for all assessment activities (see Figure 7A-1 for an example). They found the rubrics to be helpful and precise and said they guided their learning. Student P5 explains that '[...] the rubrics made this course so easy to follow and clear in terms of what is expected and what I am supposed to know at the end', while student P14 emphasised that rubrics should not just cover the ideal but be able to cater for the variables in all tools. Jones (2005) mentions similar points when discussing the importance of rubrics in constructionist assessment. P29 further highlights that whether the assessment activities involved peer or facilitator assessment, the rubrics helped her to implement what she had learned, and it offered her valuable feedback for improvement (Ragupathi & Lee 2020). Allen and Tanner (2006) highlight the importance of using rubrics to guide students' understanding of goals and expectations when completing activities.

It was not surprising to see that some participants expressed their concern about the lack of traditional teaching. This was unfamiliar territory to most students, and the constructionist learning theory left them with a sense of discomfort, especially the part where they first needed to engage by themselves (see Figure 7.3), construct meaning and then engage with others. P12 mentions, '[...] a bit vague, I felt we had to do almost all the work ourselves [...]', showing the restlessness and sense of abandonment related to working alone without being taught. They were not used to self-directed learning and being responsible for their own work.

□ Facilitator (teacher)

Participants in this study strongly felt that the facilitation strategies used influenced their attitude to participate in the course. Students perceived the facilitator's role in learning and assessment to be guiding and positive, portraying a good attitude towards e-learning and providing feedback (P25).

Student P8 highlights that: 'Opinions from peers and facilitators gave another perspective than your own and assisted in improving' (P8, age unspecified, date unspecified).

The attitude of the facilitator seems to have played a great role in encouraging student performance, as expressed by students P24 and P29:

> 'Facilitators have a very positive attitude towards us as adult students and they try to explain where we did not understand.' (P24, age unspecified, date unspecified)

> 'The facilitators had a very positive vibe; it made all the hard work worth it. It made me want to do well. The fact that there was a test before each lecture forced me to read.' (P29, age unspecified, date unspecified)

Literature emphasises the effect of a positive facilitator attitude on students' willingness to learn and engage online (Freeman et al. 2010). In addition, their perceptions of teaching and learning changed as they were challenged through the use of ICT's and constructionist approaches. Students found it to be comforting to work with their facilitators and peers, as expressed by P12: '[H]aving to work with my peers and have my facilitator along my side to explain and clarify has been amazing' (P12, age unspecified, date unspecified).

Technology

With the use of ICTs being a fundamental component of the course content and a primary component in blended learning constructionist approaches, it was evident that technology played a major role in the assessment and learning (see Figure 7.4 and Figure 7.5). The variety of technology used drove the success of this study; however, the module used the technology to support learning and assessment, as P27 and P28 mentioned:

> 'There are tools that I was introduced to that I had not used before. I was shown creative and interesting ways of using Microsoft PowerPoint; that was my wow moment.' (P27, age unspecified, date unspecified)

> 'I have clearly benefited. There is a wide range of tools available, but one does not always have the time to explore them all. Exploring them with guidance has been most useful.' (P28, age unspecified, date unspecified)

The computer-based assessment was used as a form of self-assessment. Each class started with a short quiz about the readings around the topic under discussion for the week. The test was also used as a baseline test to see if the students prepared for class. The participants found these tests ineffective in that students did not find value in it. This aligns with the findings of Cole et al. (2000), who highlighted that computer-based assessments do not work well in constructionist learning. This was explained by P5 as: '[*T*]he tests where [we] were also not effective; I don't think I learned anything from these tests but rather from the practical work' (P5, age unspecified, date unspecified).

This is an indication that the students prefer the constructionist approach, where they have to discover and construct knowledge by interacting with themselves and others and using ICT to create an artefact (Papert & Harel 1991; Rosenfeld et al. 2019).

☐ Support

For this study, all institutional resources and management were provided. Students are registered on the LMS of the University, and they have access to dedicated computer labs where they can access the LMS. Campus-wide Wi-Fi Internet access is available to all registered students so that they can access the LMS as well as browse the Internet for any additional information. Students were also aware of the resources they needed to have in order to complete the module. These resources include a smart device such as a laptop where they can work when they are not on the university's premises. Additional resources in the form of ICT tools that they would use in the course for learning and assessment were provided. These tools are all free tools and do not require any subscription fees. P1 confirmed that the institutional support was sufficient:

> 'Yes, there was sufficient support. Our activity was mostly done on computers and the institution has so many available computer labs and if one chooses to use their laptop the Wi-Fi is available.' (P1, age unspecified, date unspecified)

Students felt motivated and encouraged by their peers and facilitators to try new ICT tools and expand on their existing knowledge and skills. As two students mentioned:

> 'Yes, we supported and helped each other, and I think without that, the course would have been boring or not as interactive. Sharing of technology also made the experience better.' (P6, age unspecified, date unspecified)

> 'I started off using TalentLMS for the LMS assignment. I found this really difficult to use. This assignment frustrated me, but the peer support in CEL is priceless.' (R4, age unspecified, date unspecified)

Although students relied on each other, they also felt that the facilitators were very supportive, were readily available and attended to queries (P27). The constructionist environment provided a safe and secure space for exploration and discovery. P26 emphasises that although she had a tendency to use well-known tools, trying out the tools that the facilitators suggested intrigued them '[...] in assignments, even when I preferred sticking to what I know, using the alternative tools expanded my abilities'. This instigated an attitude change towards the use of ICTs for learning and assessment.

☐ Student

Learning through self-assessment and peer assessment was well accepted. To make sure that students learn from their own efforts and peer feedback, each week has at least one individual activity that is followed by a peer assessment. Students appreciated the assessment activities as positive learning experiences that they shared with their peers. They experienced a sense of group cohesion which manifested in being motivated and encouraged to continue participating. P13 claims that it '[...] motivated me to know that it's possible; I can also do it'.

During peer assessment, students had the opportunity to improve on their activity after they received feedback. Students really benefited from sharing their work as they saw the value of learning and questioning, as explained by P11, 'I liked the part where we had to give feedback on our assignments'.

P6 expressed the benefits of peer assessment as 'doing peer assessment and learning together helped cover more content quicker'. This was supported by P21, 'I must admit the group work and peer assessment and be[ing] given opportunities to cooperate and collaborate with peers helped me learn'.

P25, however, raised the concern that was also found in the literature by Falchikov and Goldfinch (2000):

> 'Most of the assessment strategies were fine, although I feel peer assessment is unreliable at times for the assessor because we are kinder to each other as peers. However, it builds far less stress and anxiety, if you know that a tool or activity will be assessed by your peers.' (P25, age unspecified, date unspecified)

This proves that there are motivating aspects to peer assessment that encourage learning as it gives students the freedom to demonstrate their knowledge and skills. The sense of confidence and comfort encourages learning. Students are in fact aware of possible unreliable assessment from peers; however, the focus is taken away from the assessment and rather channelled towards the learning that comes from the assessment activity. Peer assessment provided them with a space to collaborate with one another and communicate both f2f and online. This is a primary component of constructionism. P28 emphasises that:

> 'Face-face was very necessary still as a lot of online instruction and content left you with questions. Therefore, class scheduled times were very important for questions as well as peer assessment and grading and group work. Time was never wasted, and at the end of every session it felt as though it was time used productively.' (P28, age unspecified, date unspecified)
>
> 'Most of the time you learned the most by peer assessment in class and learning from what others learned during their instructions.' (P28, age unspecified, date unspecified)

Discussion

The study confirms that the six dimensions found in the conceptual framework work collectively to enhance assessment and learning using a constructionist approach. Numerous small activities give students the freedom to create, build and share knowledge and skills, which contributed to a final assessment. As students had the opportunity to improve on their activities and apply what they learned in different topics, they felt a sense of empowerment and confidence to practise and implement their new skills in their authentic environments.

Although the constructionist approach to teaching, learning and assessment was new to the students, they did manage to adapt to it. They experienced the content of the course as well thought-through and well-presented, making it easy to follow and understand. In addition, they found value in the attached rubrics and claimed that it guided them while preparing their activities.

The strategies used by the facilitators encouraged students to discover, make, engage, create and participate in all the activities. Although they were not used to constructionism, it made them dependent on their peers for support, encouragement and assistance. They found comfort in having a support network in their peers and facilitators.

Students were accustomed to using technology but still found the number of technology tools (Figure 7.5) used daunting and felt that the short time that they spent exploring each of the tools was not enough to fully grasp how to use it. However, it did open their minds to what is available and possible to use in their training environments.

Support was mostly provided by the facilitators and peers. As this module was part of the formal classes of the university, all systems (computer labs and Internet access) were in place and working. It is worth noting that if this was not the case, students would have struggled to explore the number of technology tools that were expected from them.

Peer influence played a huge role in this constructionist course. Students self-proclaimed that they would not be able to do the course if it were not for the strong emphasis on peer interaction. Their peers encouraged them to work, even if they were demotivated. The attitudes and motivations of the students were influenced by their peers. However, some were not in favour of the many peer assessments, even though they did not mind doing the assessment. They still wanted the facilitator to assess them and give feedback. In their eyes, that would be how they learn from the experts.

Conclusion

It is evident that there is a very close relationship between constructionist learning and assessment. The idea of constructionist assessment is so deeply intertwined in constructionist learning that it is almost impossible to have one without the other. With careful design of material and explicit details of assessment, constructionist assessment can be very fruitful, as students do understand the value in the nature of activities. All forms of assessment need to be carefully structured to provide students with the confidence and comfort to share with their peers and facilitators. This is where the learning takes place. To alleviate subjectivity and promote reliable, authentic and fair assessment, rubrics that clearly and precisely outline the criteria need to be provided. A working environment that gives students the freedom to explore, share, create and critically solve problems practically really demonstrates the affordances and benefits of constructionist assessment and learning. Students want to have an active role in assessment where they can demonstrate their abilities and share their knowledge.

However, ICTs played a key role in this constructionist learning and assessment module. As the module is about computers and e-learning, one tends to minimise the importance of ICT and e-learning tools. Students enrolled in this module constructed knowledge (through interaction with themselves and others) and created e-learning artefacts using ICT and e-learning tools. Participants agreed that the variety of tools was overwhelming, but at the same time, it encouraged them to explore, ask for assistance and eventually manage the tools. For example, taking Microsoft PowerPoint to the next level by adding hyperlinks opens up many possibilities of creating engaging presentations. From this study, it is clear that the use of ICTs to enhance and transform constructionist assessment and learning has been shown to positively influence students towards a future-focused mindset to teaching and learning.

The overall experience of the module showed that most of the students enjoyed the constructionist approach to learning and assessment, and students were now moving towards being independent lifelong students open to educational change and the inclusion of ICTs in teaching and learning. The majority of the response keywords indicated that students had a positive experience regarding the design of the course. They described it as *good*, *well-thought-through*, *interesting*, *interactive* and *fun*. Only a few of the response keywords were negative, and this was a result of perceived overload to the module. Students reiterated that time reserved for assessment activities was too conservative and this left them *frustrated*, *confused*, *pressured* and *overwhelmed*.

A limitation to this study is that it focused on adult students who would really benefit from constructionist assessment as they wished to practise it in their disciplines. Therefore, there was an openness to experiential learning of constructionist assessment and learning from the onset. Another limitation is that the content lends itself well to constructionism as a whole, and this may not always accommodate for all disciplines. It is recommended that future studies focus on using constructionist assessment in other disciplines and among different groups of students to reveal the benefits and confirm the affordances of this approach and the use of ICTs in teaching and learning that could promote 21st-century skills.

One of the student reflections (R1) demonstrates the success of an ICT-drenched constructionist approach to learning and assessment:

> 'The most powerful learning moment was when I realised that I was using the constructionist theory to learn and explain the constructionist theory. This was so powerful because I suddenly understood the theory 100% because I was doing it the whole time.' (R1, age unspecified, date unspecified)

Chapter 8

The effect of teacher professional development in the adoption of ICT in teacher practices in Gauteng province

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Abstract

This is a case study on the digital literacy programme intended to capacitate Gauteng province in-service teachers in the utilisation of information and communication technologies (ICTs) for teaching and learning. The training programme was based on the adaptation of the UNESCO ICT-CFT. The study sought to determine the extent to which this information and communication technology (ICT) professional teacher development programme improved the utilisation of ICT to teach specific subjects by teachers who participated in the

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programme. This was a descriptive quantitative study that utilised pre- and post-test scores. The questionnaire was administered to 3 112 participating teachers. Probability sampling was used as all teachers who participated in the training programme rolled out to 476 schools in the ICT project had the same chance to complete the questionnaire that was distributed through Google Forms. Descriptive statistics were used to analyse the quantitative data. The results of this study indicate that there was an improvement in the participating teachers' adoption and integration of ICTs into subject teaching. The lesson learned from this research is that the extent to which an ICT teacher-training programme succeeds is dependent on its priorities in the rollout of the project in terms of its approach, provisioning of ICT infrastructure and e-content.

Introduction

The South African ICT in Education policy, the *White Paper on e-Education* (Department of Basic Education [DBE] 2004), advocates for the transformation of teaching and learning using ICT in line with the *Curriculum and Assessment Policy Statement* (CAPS 2012) and the DBE ICT framework for Teacher Professional Development (2017). The *White Paper on e-Education* (2004) informed the development of the Guidelines for Teacher Training and Professional Development in ICT and Training (DBE 2007) with the objective of specifying ICT knowledge, skills and values that educators require to effectively deliver the national curriculum. Despite a well-articulated policy environment in the integration of ICT for teaching and learning, Du Plessis and Webb (2012) argue that teachers lack adequate ICT competencies to purposefully utilise ICTs in teaching and learning.

The digital literacy programme under study was introduced to capacitate teachers in the Gauteng province with knowledge, skills and attitudes to integrate ICT into teaching and learning. The programme is offered as a skills development programme targeting in-service teachers who have been provided with ICT resources in the form of laptops with the Microsoft suite and SMART boards with SMART notebooks that are used to access content, prepare lessons and deliver content in the classroom. The programme has ten notional hours and is endorsed by the South African Council of Educators (SACE). This intervention is delivered onsite within the schools as part of providing just-in-time support by ICT trainers who predominantly have teaching qualifications in addition to receiving training on how to train and support teachers in using ICTs for teaching. The training materials are delivered through print materials and in USB memory sticks to teachers.

Research problem

The e-readiness study conducted by Dlamini (2017) indicates that teacher ICT skills in the Gauteng province in South Africa are at a foundational level despite huge investments committed to transforming teacher practices as well as learner results. These assertions are supported by Padayachee (2017), who reports that the quality of the National Senior Certificate results is still very low. A view shared by Du Plessis and Webb (2012), who attributed these poor educational outcomes to educators' inability to stimulate attitudes of curiosity as well as fostering critical thinking skills in learners. Therefore, this study seeks to provide evidence regarding the appropriateness and suitability of the digital literacy programme that was informed by the UNESCO ICT-CFT in preparing teachers for subject-specific teaching with ICTs. The following aims and research questions guided the exploration of this study.

Research aim

The aim of this research is to determine the effect of the digital literacy programme on the adoption and integration of ICT into teaching and learning.

Research question

The following research question guided this study: *To what extent did the digital literacy programme improve the adoption and utilisation of ICT teaching resources in schools?*

Significance of the study

The literature search for this research (Mizell 2010; Ndlovu 2015; Tondeur et al. 2008) identified a few studies in South Africa that have focused on the effect of ICT TPD that offers subject-specific training content. This study has implications that are important for teacher development programme designers as well as policymakers regarding the design and delivery of ICT TPD programmes. The results of this study are useful in demonstrating the effect of ICT TPD strategies that may have repercussions on teacher readiness to adopt and integrate ICTs into their subject teaching.

In our search for literature, it was difficult to identify ICT studies that have evaluated ICT training programmes. Tondeur et al. (2018) did a multilevel analysis of what matters in the training of preservice teachers with regard to ICT competencies. In their study, they focused on testing a model to explain preservice teachers' perceived ICT competencies. Vitanova et al. (2015) also conducted a study to identify factors that affect teacher development of ICT competencies. In their study they did not provide a description of the programme that teachers had participated in, and the focus was limited to teacher perceptions.

Professional teacher development

Prestridge (2010) describes ICT PD as teacher-training programmes that relate to computer-based devices and contends that the curriculum of these programmes is limited to the development of operational skills for different types of digital tools. Li et al. (2019) identified the following six factors that can improve the outcomes of teacher ICT PD. These were (1) professional competency in educational ICT use, (2) collaboration for ICT integration, (3) benefits of ICT use, (4) autonomy to innovate, (5) recognition as a professional and (6) skills and practices in the educational use of ICT. These factors mainly relate to human capacity, interaction and affordances of ICTs that the design and delivery of training programmes should consider.

The TPD sector is highly regularised in South Africa as guidelines on how teacher development should be administered for teachers is provided in its policies. The following documents are significant in educator PD:

1. Norms and Standards for Educators.
2. The Code of Conduct of SACE.
3. The Developmental Appraisal Manual.

The various policies should either directly or indirectly guide the work of educator development providers, whether they deliver preservice or in-service programmes. However, the success of their implementation depends on the training frameworks, resources and outcomes they seek to achieve.

The main policy documents that guide TPD in ICT are the *White Paper on e-Education* (DBE 2004) and the DBE ICT framework (2017). Hammond et al. (2017) posit that effective TPD should be structured and that learning outcomes should aim at changing teacher practices and improving student results. Given the policy frameworks presented, it is expected that professional teacher development in South Africa should be efficient and effective in the integration of ICT into teaching and learning.

An analysis of different policies developed with regard to TPD in South Africa reveals that the state of TPD is complex and multilayered, as presented by the *SACE Act 31 of 2000*. It states that there are three levels in which PD is offered to educators: level one is teacher-driven, level two is school or institution-driven and level three is service provider–driven. Each of the levels contributes to the capacitation of the teachers and the dosage and effectiveness of the training determine the extent to which teachers gain confidence in integrating ICTs into teaching and learning (Peralta & Costata, 2007).

Information and communications technologies integration

Mishra and Koehler (2006) described ICT integration using the components of content, pedagogy and technology. Mishra and Koehler (2006) developed a TPACK model, which has a significant impact on how teachers integrate technology within their classrooms. Technological, pedagogical and content knowledge deals with teachers' PCK in relation to technology. This framework emphasises the understanding of the relationships between technological, content and PK within teachers (Mishra, Koehler & Kereluik 2009).

Research on instructional technology conducted by Koehler et al. (2014) reveals that teachers lack the knowledge to successfully integrate technology into their teaching and their attempts are limited in scope, variety and depth. In our viewpoint, this could be attributed to a lack of clear developmental indicators on the TPACK model as it does not clearly state what outcomes of competency are expected in each of the knowledge components identified in the framework. This becomes a challenge in a case where a teacher requires a description or demonstration of how to effectively integrate ICTs in their specific discipline.

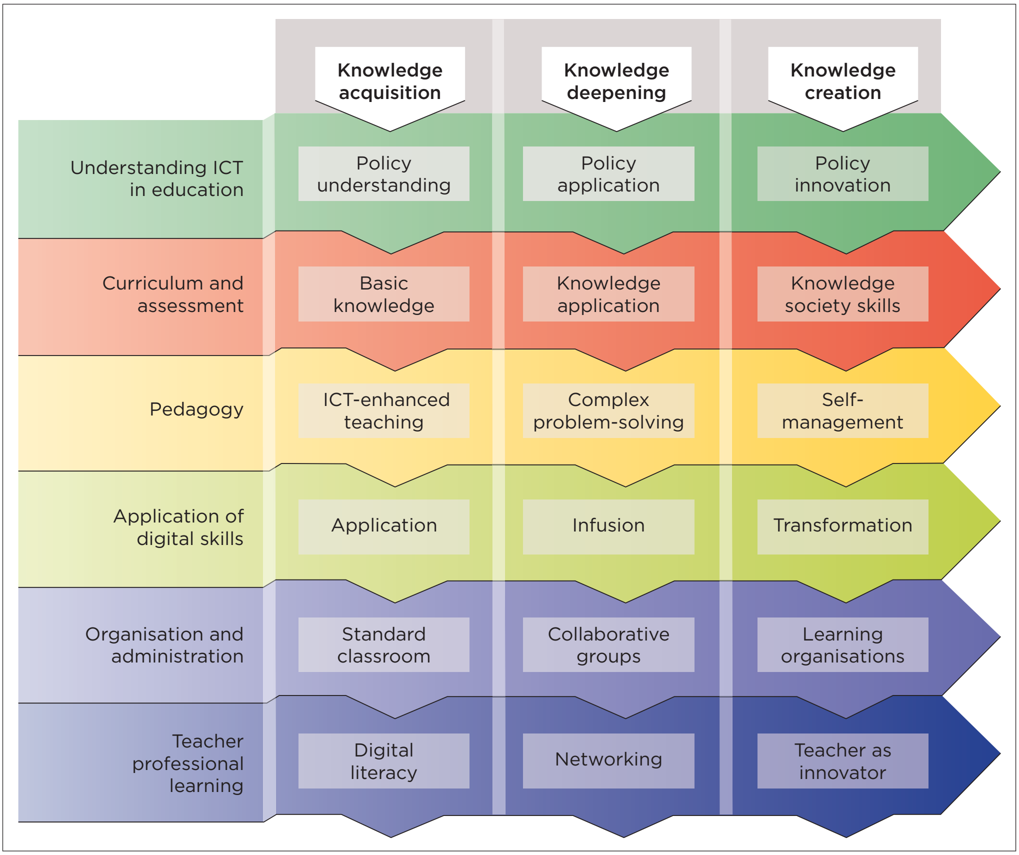
While Ndlovu (2015) argues that the integration of ICT in South African schools is well articulated in the *White Paper on e-Education* (DBE 2004), results from several studies (Ndlovu & Moll 2016; Padayachee 2017; Tondeur et al. 2007) indicate that there is a gap between proposed ICT policies and the actual use of ICT in the classroom. Some of the challenges around the integration of ICT are conceptual (Chai et al. 2010; Mishra & Koehler 2006; Hakkarainen 2009), as there is no consistent understanding of what integrating ICT into teaching and learning entails. The success of teacher development competencies in ICT through training should and can be determined by the framework that teachers adopt and the extent to which the teachers adapt it in the teaching of their subjects.

Teacher competency framework

According to Mills et al. (2020), a competency framework is a set of organised, related and processed competence statements. Thus, each entry has a range of levels which are related to specific dimensions. The digital literacy programme under study adopted the UNESCO ICT-CFT (2019) version 3 competency model presented in Figure 8.1, as its competences seem to capture core teacher practices. The aim of the framework is (UNESCO 2018):

> [*T*]o inform teacher-training policies and programmes to strengthen the use of ICT in Education. Its target audience is teacher-training personnel, education experts, policymakers, teacher support personnel and other professional development providers. The ICT CFT assumes a working knowledge of the benefits of ICT in education and encourages contextualization and adaptation of teacher professional development as relevant. (p. 7)

The UNESCO ICT-CFT (2019) framework consists of three levels of progression; firstly, knowledge acquisition involves increasing the usage of technologies in society. Secondly, knowledge deepening focuses on the skills and ability to use technologies within society. Thirdly, knowledge creation involves creating new knowledge using ICTs. This framework illustrated later enables programme developers to create differentiated training materials.



Source: United Nations Educational, Scientific and Cultural Organization (2018).
Key: UNESCO, United Nations Educational, Scientific and Cultural Organization; ICT, information and communication technology; CFT, Competency Framework for Teachers.
FIGURE 8.1: UNESCO ICT-CFT, version 3.

This framework has six core teacher competencies that should be developed, and these are (1) understanding ICT in education, (2) curriculum and assessment, (3) pedagogy, (4) application of digital skills, (5) organisation and administration and (6) TPD. These six areas are expressed using 18 competencies. Owing to its limitations, this study has focused on four areas, which are the application of digital skills, pedagogy, organisation and administration and curriculum and assessment. The reason is that these are more relevant for in-service teachers whose main task is to deliver content to learners with ICTs. It therefore sought to find out if teachers use the relevant application software they had been trained on in the teaching of their subjects.

One challenge noted in the implementation of frameworks on the infusion of ICT into teaching and learning is the absence of guidelines on adapting them to the South African context (Du Plessis & Webb 2012). This has resulted in many researchers creating their own guidelines (Leendertz et al. 2015),

TABLE 8.1: Learning progression.

Designed stage	Criteria
Level 1 (beginner)	• The teacher does not use any word processor, spreadsheet or presentation software for lesson preparation *or* lesson delivery • Does not use SMART Notebook or interactive flat panel lesson preparation for lesson delivery
Level 2 (intermediate)	• Does use a word processor, spreadsheet or presentation software for lesson preparation or lesson delivery • Does use a SMART Notebook or interactive flat panel for lesson preparation *or* lesson delivery
Level 3 (advanced)	• Does use a word processor, spreadsheet or presentation software for lesson preparation *and* lesson delivery • Does use SMART Notebook or interactive flat panel for lesson preparation *and* lesson delivery

which makes a comparison of different studies inconsistent. This study has adapted the UNESCO ICT-CFT standard competency guideline for teachers (UNESCO 2008) to suit the South African context, as shown in Table 8.1. The levels are defined as follows.

This study assumes that teachers' use of ICTs strays across the three levels, and this is to be expected as their competencies depend on variables such as the experience they have had in working with the tool. The training they are offered augments what they can do and gives them ideas on how to use ICTs for teaching their subjects.

Research design

A quantitative research method was deployed to establish the extent to which teachers have adopted the use of ICTs for accessing content, planning and delivering lessons in their classrooms.

Population and sample of the study

The population target was 116 schools in the ICT Schools of the Future Project from all 15 Gauteng province districts in South Africa. The schools were comprised of fee-paying public schools, non–fee-paying public schools, schools of specialisation (*focusing on skills and knowledge required in specific industries*) and twinning schools (*partnership of schools with resources and those who do not have*). The total teacher population of the 116 schools is projected at 8 000. The survey distribution predominantly focused on secondary schools, although there were a few primary schools. Consequently, all respondents from the survey were 3 233. However, in the cleaning of the data, 121 participants were disqualified as they did not complete both questionnaires *(pre- and post-test)*, while 3 112 completed both, representing 96.3% of the sample. In order to generalise the findings for the whole province, the study required a minimum of 50% respondents with a significance level of $p = 0.05$ at 95% confidence interval (Krejcie & Morgan 1970), which required 383 participants. Both the schools and educators were sampled through the purposive sampling method, with the educators volunteering to participate. The educators' privacy was preserved as their responses and names were not shared with the schools or their employers. In addition, participating educators could withdraw at any stage during the survey.

Instrument

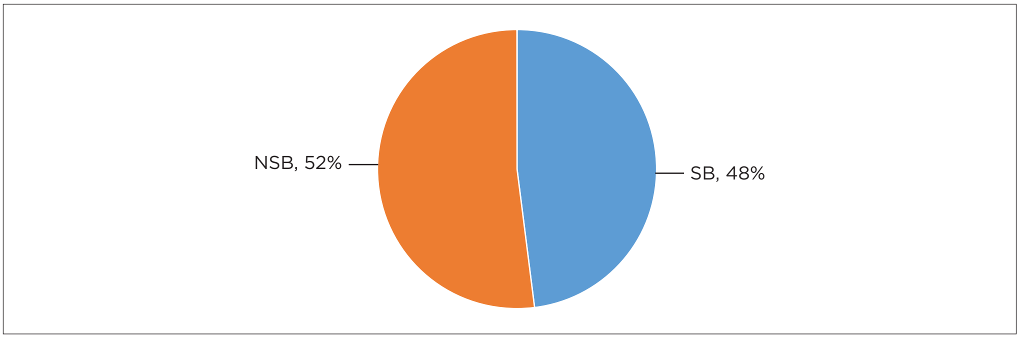
Matthew Goniwe School of Leadership and Governance (MGSLG), a training institute for the Gauteng Department of Education, developed the training evaluation instrument. The instrument had 28 questions with ICT competence variables for the following application software, SMART Notebook, word processor, spreadsheet processor and presentation application. These instruments were delivered through a *Google Form* and the results were collected via *Google Sheets*.

This research used a secondary data source whose data are from a nonexperimental quantitative research method. A set of closed-ended questions were used for data-collection in the survey. Only specific questions relating to integration were selected. The questionnaire was deployed to willing participants without taking into cognisance their teaching background, gender, race, qualifications and teaching experience. The pre-evaluation prior to the training was administered in three days and training took place between February 2018 and the end of October 2018. Henceforth, training was implemented for ten months, culminating in the post-evaluation, where responses were collected within three days.

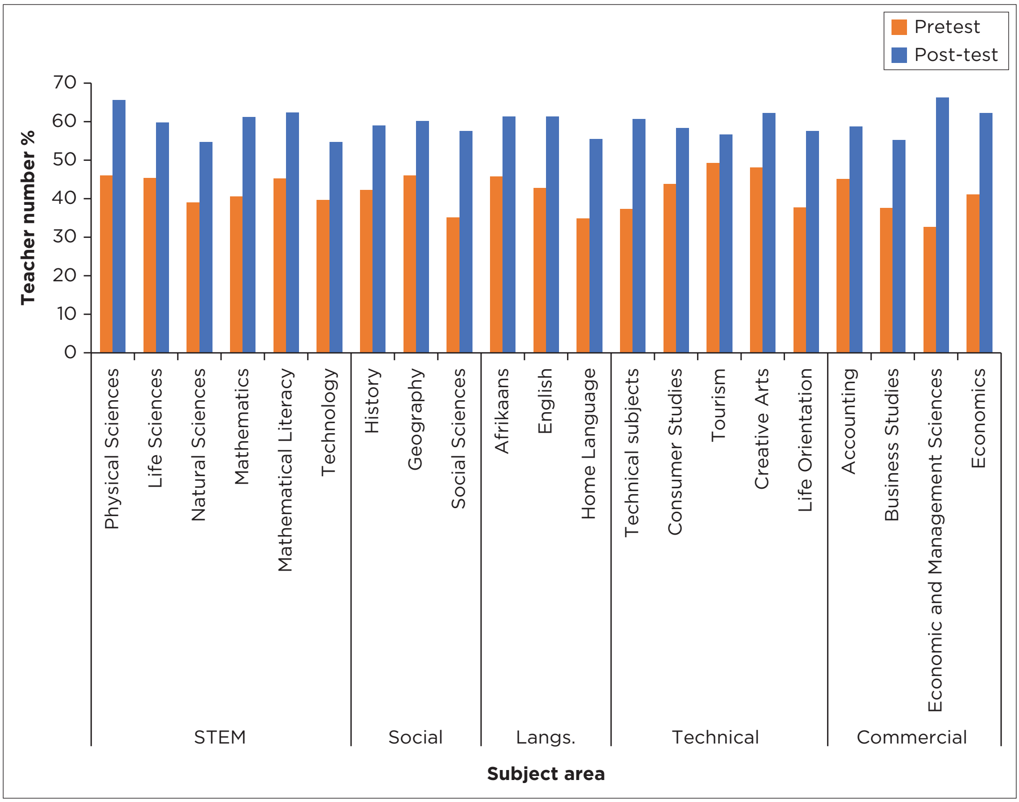
Analysis of data

Numerical data gathered were analysed quantitatively using Microsoft Excel. Descriptive statistical methods were used to analyse the data to answer the proposed research questions. Descriptive statistics in terms of mean was used to answer the research questions on how teachers are utilising ICT resources and the extent to which the training programme has affected their knowledge and skills. Around 48% of the participating schools have smart boards in their classrooms, indicating a disproportionate distribution of smart boards, as shown in Figure 8.2.

The disproportionate distribution of smart boards affected the resources used for teaching and learning. There is evidence in the pretest that teachers used different tools to carry out different tasks in their teaching. Figure 8.3 recorded higher numbers of teachers using any ICT for lesson preparation, which means that they could have used the word processor (MS Word) or the



Source: Author's own work.
Key: NSB, non-smart board; SB, smart board.
FIGURE 8.2: Distribution of smart boards.



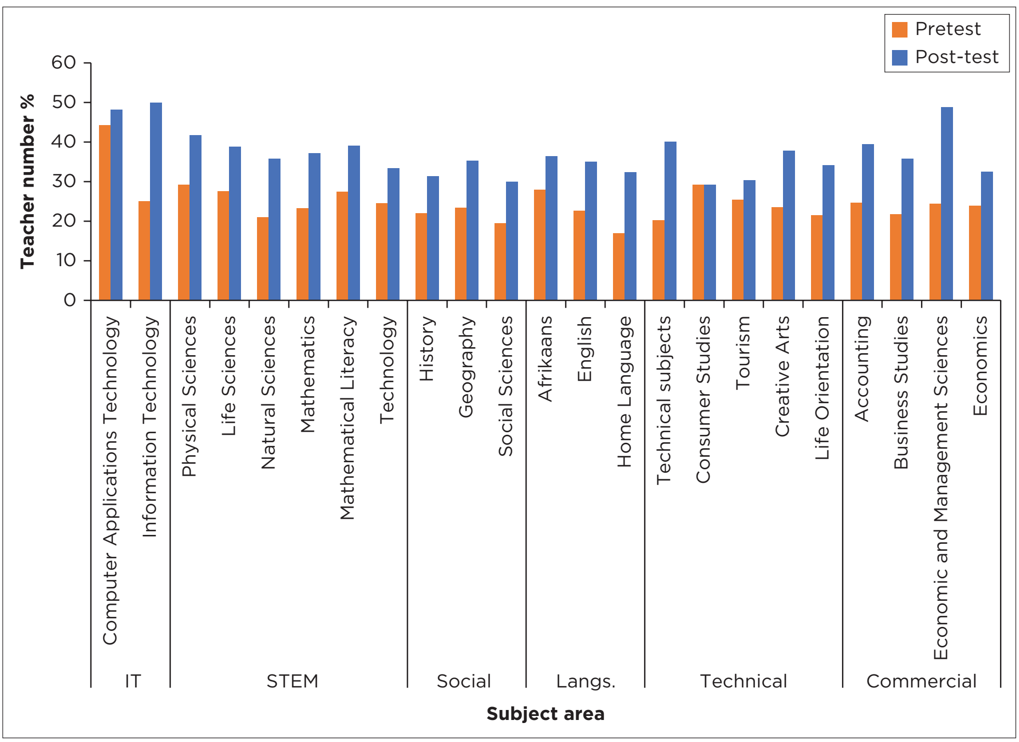
Source: Author's own work.
Key: MS, Microsoft; STEM, science, technology, engineering and mathematics; Langs., languages.
FIGURE 8.3: The effect of training on word processor competence.

SMART Notebook for the same purpose. At the same time, they could have used both presentation software (Microsoft PowerPoint or SMART Notebook) for lesson presentations.

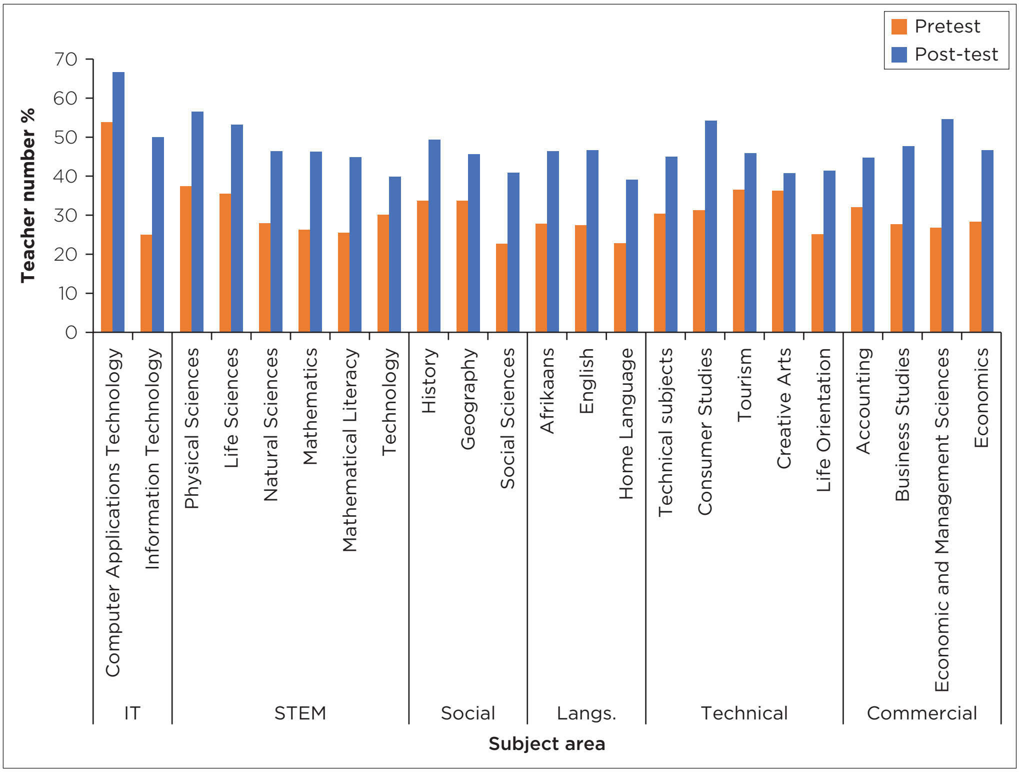
The focus of this study was on using responses to teacher use of the word processor, presentation, spreadsheet and interactive board for their teaching practices that are presented in the figures mentioned later and use of these applications entails lesson planning, assessing, teaching and accessing content with and through available tools. Figure 8.4 presents the results of this study that are based on the pre- and post-tests on the use of word processor applications. Each subject taught in these schools has been captured.

The maximum percentage recorded for the pretest was 63.5% in Computer Applications Technology and 80% post-test in IT. Both subjects are offered in the Further Education band, and this indicates a huge improvement in knowledge and skill development. The minimum score recorded was 32.6% in Economic Management Sciences, which increased to 54.6% in Technology; both subjects are offered in Senior Phase. The average score in the utilisation of MS Word for all subjects was 42.4% and a post-test mean of 60.9%. This indicates improvement in skills and knowledge.

The maximum test score recorded for Microsoft Excel was 44.2% in Computer Applications Technology for the pretest and 50.0% in IT for the post-test. The minimum score recorded for the pretest was 17% in Home Languages – in this case, African languages – and the post-test was 29.2% in Consumer Studies. The mean recorded for all the subjects was 24.7% pretest while the post-test was 37.1%, which also shows an improvement, although the increase is still below an average of 50%.



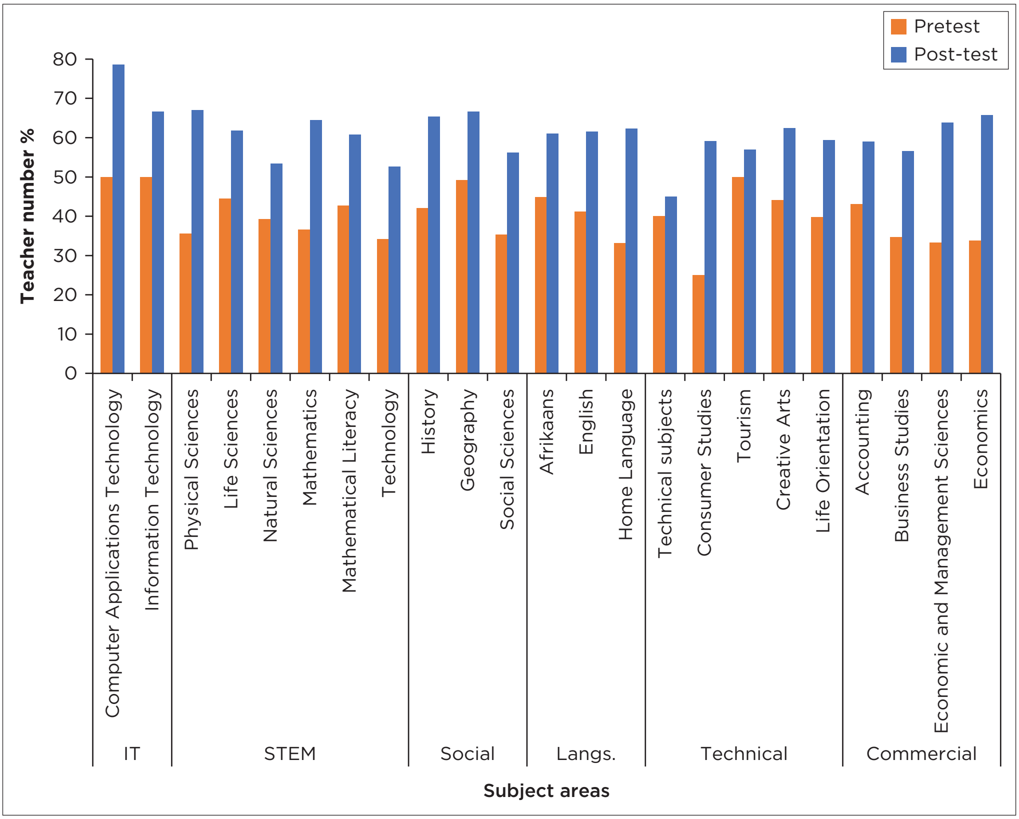
Source: Author's own work.
Key: MS, Microsoft; IT, information technology; STEM, science, technology, engineering and mathematics; Langs., languages.
FIGURE 8.4: The effect of training on spreadsheet competence.



Source: Author's own work.
Key: MS, Microsoft; IT, information technology; STEM, science, technology, engineering and mathematics; Langs., languages.
FIGURE 8.5: The effect of training on Microsoft PowerPoint competence.

The maximum recorded for the pretest was 53.8% in Computer Applications Technology and the post-test maximum was 66.7% in the same subject (Figure 8.5). The minimum score recorded for the pretest was 50% in IT and the post-test minimum was 53.8% in Computer Applications technology. The mean score for all the subjects was 30.6% for the pretest and 47.5% for the post-test, indicating an increase which is still below the 50% average.

The maximum test score recorded for the SMART Notebook (Figure 8.6) was 50% in pretest by Tourism and IT and the maximum test score for the post-test was 78.6% by Computer Applications Technology. The minimum score recorded for the pretest was 25% in Consumer Studies and the minimum post-test score was 45% in Technical Studies. The mean score for all the subject pretests was 40.1% and the post-test score was 61.2%, showing a positive improvement. It is noteworthy that while these schools have smart boards, not every educator has equal access to it as the smart board-to-teacher ratio is very low. Consequently, the teacher might prepare their work on laptops; however, the means to project their work is dependent on the availability of a smart board or data projector.



Source: Author's own work.
Key: MS, Microsoft; IT, information technology; STEM, science, technology, engineering and mathematics; Langs., languages.
FIGURE 8.6: The effect of training on SMART Notebook competence.

Discussion

The use of the UNESCO ICT-CFT framework to design this programme appears to have been effective and adequate in capacitating teachers on the use of productivity tools based on the results discussed earlier. However, the training strategy of grouping teachers according to their subject specialisation appears to have been adequate in aiding the adoption of ICT for classroom use. According to Abdullah (2009), there are several factors that affect ICT integration in schools, including inadequate teacher ICT development programmes, infrastructure, teacher workload, change management and time management. It is in the interest of this chapter to determine if there was an improvement in the adoption of ICTs by teachers based on their participation in the digital literacy programme.

Teacher use of ICT resources and applications

The results indicate a positive improvement in the use of productivity tools for teaching and learning. The emphasis of the training programme appears to

TABLE 8.2: Mean scores of pre- and post-test subject-specific integration.

Subject	MS Word		MS Excel		MS PowerPoint		SMART Notebook	
	Mean	Average mean	Mean	Average mean	Mean	Average mean	Mean	Average mean
Accounting: Pretest	45.1	13.6	24.7	14.8	32.1	12.7	43.1	15.9
Accounting: Post-test	58.7		39.5		44.8		59.0	
Economic and Management Sciences: Pretest	32.6	33.7	24.4	24.4	26.7	28.0	33.3	30.6
Economic and Management Sciences: Post-test	66.3		48.8		54.7		63.9	
Economics: Pretest	41.0	21.2	23.9	8.5	28.4	18.2	33.8	32
Economics: Post-test	62.2		32.4		46.6		65.8	
Business Studies: Pretest	37.6	17.6	21.8	14.0	27.7	19.9	34.6	22
Business Studies: Post-test	55.2		35.8		47.6		56.6	
Creative Arts: Pretest	48.0	14.2	23.5	14.3	36.3	4.5	44.1	18.4
Creative Arts: Post-test	62.2		37.8		40.8		62.5	
Technical Areas: Pretest	37.3	23.3	20.3	19.7	30.4	14.6	40.0	5
Technical Areas: Post-test	60.6		40.0		45.0		45.0	
Hospitality Studies: Pretest	100.0	0.0	100.0	−75.0	100.0	0.0	0.0	0
Hospitality Studies: Post-test	100.0		25.0		100.0			
Tourism: Pretest	49.2	7.4	25.4	4.9	36.5	10.4	50.0	6.9
Tourism: Post-test	56.6		30.3		45.9		56.9	
Consumer Studies: Pretest	43.8	14.5	29.2	0.0	31.3	22.9	25.0	34.1
Consumer Studies: Post-test	58.3		29.2		54.2		59.1	
Life Orientation: Pretest	37.7	19.9	21.5	12.6	25.1	16.3	39.7	19.6
Life Orientation: Post-test	57.6		34.1		41.4		59.3	
Information Technology: Pretest	37.5	42.5	25.0	25.0	25.0	25.0	50.0	15.7
Information Technology: Post-test	80.0		50.0		50.0		66.7	
Computer Applications Technology: Pretest	63.5	6.9	44.2	3.9	53.8	12.9	50.0	28.6
Computer Applications Technology: Post-test	70.4		48.1		66.7		78.6	

Table 8.2 continues on the next page →

TABLE 8.2 (cont.): Mean scores of pre- and post-test subject-specific integration.

Subject	**MS Word**		**MS Excel**		**MS PowerPoint**		**SMART Notebook**	
	Mean	**Average mean**	**Mean**	**Average mean**	**Mean**	**Average mean**	**Mean**	**Average mean**
Afrikaans: Pretest	45.7	15.6	27.9	8.6	27.9	18.5	44.9	16.1
Afrikaans: Post-test	61.3		36.5		46.4		61.0	
English: Pretest	42.7	18.6	22.6	12.4	27.4	19.2	41.1	20.5
English: Post-test	61.3		35.0		46.6		61.6	
Home Language: Pretest	34.9	20.6	17.0	15.4	22.8	16.3	33.2	29.1
Home Language: Post-test	55.5		32.4		39.1		62.3	
Geography: Pretest	45.9	14.2	23.3	12.0	33.7	12.0	49.3	17.4
Geography: Post-test	60.1		35.3		45.7		66.7	
History: Pretest	42.2	16.8	22.1	9.3	33.8	15.6	42.1	23.3
History: Post-test	59.0		31.4		49.4		65.4	
Social Sciences: Pretest	35.2	22.3	19.5	10.5	22.7	18.1	35.3	21
Social Sciences: Post-test	57.5		30.0		40.8		56.3	
Mathematical Literacy: Pretest	45.2	17.1	27.4	11.8	25.5	19.3	42.7	18
Mathematical Literacy: Post-test	62.3		39.2		44.8		60.7	
Mathematics: Pretest	40.6	20.6	23.3	13.9	26.3	19.9	36.6	27.8
Mathematics: Post-test	61.2		37.2		46.2		64.4	
Natural Science: Pretest	39.0	15.7	20.9	15.0	27.9	18.6	39.3	14.1
Natural Science: Post-test	54.7		35.9		46.5		53.4	
Life Sciences: Pretest	45.4	14.6	27.7	11.1	35.5	17.6	44.4	17.4
Life Sciences: Post-test	59.8		38.8		53.1		61.8	
Physical Science: Pretest	45.9	19.6	29.3	12.5	37.4	19.1	35.6	31.4
Physical Science: Post-test	65.5		41.8		56.5		67.0	
Technology: Pretest	39.6	15.0	24.5	8.8	30.2	9.6	34.2	18.4
Technology: Post-test	54.6		33.3		39.8		52.6	
Total mean		**17.9**		**8.4**		**34.0**		**20.32**

Key: MS, Microsoft.

have been more pronounced on the use of word processor as well as the SMART Notebook. The word processor could have been used for preparing lesson plan and activities, while the latter was utilised for lesson presentation. The disproportionate distribution of smart boards could be a contributing factor in technical subjects having low averages on the use of the SMART Notebook. In addition, the dominance of use of the SMART Notebook compared to other tools could be attributed to teachers accessing e-content in the form of e-books and other teaching resources installed on the smart board. Teacher responses indicate low utilisation of spreadsheets, which is assumed to be used mainly for recording test scores and in a limited way perhaps used for teaching in subjects such as Accounting and Mathematics. The low utilisation average on the spreadsheet indicates low capability confidence on the utilisation of the tool.

Subject-specific integration

The pattern of use appears to reflect the design and prioritisation of device rollout which initially sort to resource Science, Technology, Engineering, Arts and Mathematics (STEAM) subject teachers. Thus, the highest ICT adoption rate was noted in Science subjects (Mathematics, Life Science, Natural Science and Physical Science). The respondents in these subjects showed a wider range of tool utilisation in the use of productivity tools. The results also confirm that computer applications technology teachers and IT teachers have comprehensive understanding of the tools as compared to other subject teachers. African language teachers are represented as home language.

Effectiveness of the programme

The data across all four application tools indicate significant differences in teacher knowledge and skills. While the word processor and SMART Notebook performed well in pre- and post-test, these reveal the bias of training, where more dosage could have been given to these applications which are predominantly used for planning and presenting lessons. Microsoft PowerPoint and Excel did not have a significant increase indicating that teachers are less comfortable with these applications. Teachers across subjects appear to have difficulty in using Microsoft Excel because of the bad performance in pre- and post-test.

Implications

The mode of delivering this programme (onsite support and training) has enabled other subject teachers to participate in PD activities despite not having adequate ICT resources. Other factors that appear to influence adoption of ICT include the availability of e-content that teachers may use for teaching and learning. The aforementioned point could be the factor affecting integration in African languages that have been listed in this study as home language, which performed poorly in the pre- and post-tests.

Conclusion

Teachers who have participated in this programme have significantly improved their skills and knowledge of ICT. This has been translated into significantly better teacher outcomes in subject integration. Where difficulty has been experienced mainly on the use of Microsoft Excel, further studies need to be carried out to determine factors that affect the adoption and use of this application in teacher practices. Diagnosis of these constraints will inform better programme development. Evidence of subject integration shows that high percentages in pre- and post-test are biased towards prioritised subjects in the deployment of ICT resources in schools. In addition, it is assumed that CAPS (2012) have inadequate guidelines on how ICT should be integrated into teaching and learning from a policy point of view. The questionnaire revealed that there were several schools that are meant to be implementing ICTs, yet they have not been adequately resourced; this also discourages teachers from using ICT as shown by content integration measures for languages.

Part 2

ICT integration into the teaching of Mathematics, Science and Technology in teacher education

Chapter 9

Mathematics teacher educators' use of virtual tools in lecture delivery

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Abstract

The use of technology in mathematics education was heightened by the onset of coronavirus disease of 2019 (COVID-19) lockdown from March 2020. Teacher educators found themselves in the midst of having to deliver 100% of their lectures online. This phenomenon motivated this study so as to share problems as well as best practices. This research explored how Mathematics teacher educators survived the disruption of their normal teaching activities. The substitution, augmentation, modification and redefinition (SAMR) model (Bray, Oldham & Tangney 2013) (see under Table 9.1) as well as Gardner's Theory of Multiple Intelligences (2011) informed the study. Data were collected from 11 Mathematics teacher educators at a single initial teacher education institution on what affordances and constraints they faced in using digital technologies to conduct lectures. The participants gave narrations of how they used digital technologies to promote students' mathematical cognition and constitutive

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discourses. This research found that some inroads have been made in the use of information and communication technologies (ICTs) in the teaching and learning of Mathematics. Most uses of ICTs are at the substitutions and routine levels that affect regulative discourse. However, it is noted that ICTs have great capacities to individualise mathematics learning and cater for students' varied learning styles. In particular, the multiple representations enabled by ICTs helped students in proving and disproving mathematical conjectures. This helped in anchoring a deeper understanding of Mathematics. The main recommendation is that teacher educators must be self-motivated to learn technology use in their teaching. However, they still need continuous personal development (PD) to enable them to utilise the ICT resources for explorative and transformative stages which lie at the heart of mathematics teaching and learning.

■ Introduction

How have teacher educators managed to continue and sustain curriculum delivery in the face of COVID-19 university shutdowns? What new digital capabilities have they learned over that time? Given that the main educational aim is for students to gain and acquire curriculum content, how could digital tools be used to achieve that? Searle (2018) refers to learning content knowledge as related to constitutive rules, as opposed to regulative rules, which refer to generic rules that are not subject-specific but nevertheless critical to creating the environment for constitutive rules for any subject to occur.

When educators use technology in education, they are faced with many questions, particularly to address constitutive rules. They traverse landscapes that they have not travelled in their own earlier education, for which most have experienced sit-in, teacher-led lessons. Without any warning, the impact of COVID-19 accelerated the uptake of ICT-mediated teaching and learning, where educators had to conduct their work remotely from their students. The resistant adapters of technological innovation in education, the so-called laggards (Rogers 1963), were left with no choice but to adopt and adapt virtual online teaching and learning platforms if they were to be relevant. For many teacher educators, the discovery that there were already numerous teaching and learning apps not only to manage the curriculum and their students – regulative discourse (Searle 2018) – but also to deliver it – constitutive discourse (Searle 2018) – was surprising. An app is the acronym of the word application software. Wikipedia defines an app as 'a computer programme designed to carry out a specific task, typically to be used by end-users and designed to help people perform an activity'. An app is a software programme designed to perform a specific function directly for the user.

One of the most popular apps is WhatsApp, which is now used widely for rapid interpersonal communication at low costs. Subsequently, from March 2020, when lockdowns started, educational practitioners were faced with many choices of these apps, if only they knew what they were. These were not really choices, as many of them were not familiar with these apps and so could not determine the ones most suited to their purposes. In most cases, it was a hit-and-miss affair. Many practitioners were left staring into space, wondering what they were supposed to do to reach their students. Teachers did not have the technological pedagogical content knowledge (TPACK) (Koehler & Mishra 2009) necessary to harness technology to optimise the teaching and learning of Mathematics. Educators were quick to see the value of seemingly social media platforms such as WhatsApp and mobile phones to advance teaching and learning for students hundreds of kilometres away. Indeed, some students were studying from locations outside South Africa.

The most familiar technologies used were e-mails or WhatsApp to instruct students on what to read as well as issuing related tasks. This is the substitution stage of the SAMR model of Bray (2013). At this lowest level, traditional methods of teaching were intact – only that they were carried out using digital technologies. This is what Searle (2018) referred to as regulative discourse. Texts were attached to e-mails for students to engage with. Another technique was downloading YouTube videos and sharing them on related topics to students. In many instances, educators videotaped and recorded their lessons in empty classrooms which were then shared with students. Thus, this remained at the substitution level of the SAMR model (Bray et al. 2013).

In South Africa, so-called zero-rated data sites were availed to students so that they could access virtual lessons. In addition to these, free data were availed to students. There was a scurry of support for online learning. Some universities had learning management system (LMS) already in place such as Sakai, Moodle and Canvas, but most of these were used for regulative discourse (Searle 2018) and substitution of traditional teaching and management, such as recording students' attendance or posting assessments (Bray et al. 2013). Most universities adopted a policy of 'buy or rent a laptop' so that students had devices to engage in virtual learning. In essence, there was a pool of seemingly endless resources thrown at educators and their students. The real problem was how to use them to maximise teaching and learning – the constitutive discourse (Searle 2018), at the transformative modification and redefinition stages of integration of technology in learning (Bray et al. 2013).

This scenario presents a justification for the research of this chapter. In the midst of so many online resources, what computer packages and applications did teacher educators use in their mathematics teaching?

Research problem

Young, Gorumek and Hamilton (2018) distinguish between computer-assisted instruction (CAI) and CBI. Computer-assisted instruction is closely related to the Substitution and Augmentation 'enhancement of traditional teaching' lower stages of the SAMR model (Bray et al. 2013). Computer-assisted instruction is regarded as behavioural in that it refers to the 'drill and practice, tutorials or simulation activities offered in substitution or as a supplement to traditional, teacher-directed instruction' (Hicks & Holden 2007). On the other hand, CBI is regarded as the overall use of technology in teaching and learning. Young et al. (2018:44), in a meta-analysis of the uses of technology in mathematics teaching and learning, found that 'grade level, role and duration were the three most investigated moderators, and all had a high impact on effect size variation across the results of the meta-analyses examined'. Young et al.'s (2018) study found that technology use in mathematics education was more helpful in improving learner outcomes in middle and high school rather than in elementary school. An important finding in Young et al.'s (2018:52) study was that technology was more beneficial when used 'to supplement or augment instead of substitute or replace traditional instruction in the classroom'. This supports the idea that the transformative stages of the SAMR model (Bray et al. 2013) were more significant in technology use in mathematics education. This finding is important in that it shows that technology cannot replace Mathematics teachers but rather is a resource to supplement and support their practice. Young et al.'s (2018:52) study found that after about three weeks, the novelty of technology intervention wears off. Therefore, the overuse of technology in itself or its availability without other considerations may not be helpful. This suggests that greater teacher PCK and knowledge of students is needed for effective learning.

Namome and Moodley's (2021) study reported that:

> [*S*]tudent access to ICT during a lesson was significant and a positive predictor for student learning outcomes in Mathematics, while teacher integration of ICT into pedagogy as a mediating factor had a negative association. (p. 1)

This finding suggests that when students themselves initiate learning with ICT, they understand much more than when their teachers direct them to do that. This is in agreement with the notion that when students are self-driven and self-regulated in their learning, they construct meaningful knowledge for themselves (Makonye 2016). Also, this implies that students understand better when they are active participants in their learning rather than passive recipients. What might be more important, therefore, is to afford an ICT structure so that students can navigate and pick what might be of more use to them. One such framework is the SAMR model (Bray et al. 2013), which is the framework of this study.

Namome and Moodley (2021)'s study is imperative because it is well documented that just the availability of ICTs in mathematics education does not readily turn to better learning outcomes (Stols et al. 2015). In the same way, Drijvers (2015) investigated 'what works and what doesn't in computer-assisted mathematics teaching and learning'. Stols et al. (2015) found that South African mathematics teachers were very much hesitant to use ICTs in their teaching, even though such resources were seemingly abundant. As Makonye (2020:3) observed, 'the learning process is advanced through the "mathematical" activities teachers engage their learners and the resources such as information and communication technologies used in them'. Makonye (2020:3) argues that what is central are 'the discursive interactions that ought to arise around the activities and the resources used'. For ICTs to be of help in furthering learning 'open-ended programmes that encourage communication, problem-solving and conceptual development must be used' (Makonye 2020:3). These arguments reinforce the findings that availability of ICT resources cannot by themselves be change agents in learning (Namome & Moodley 2021; Stols et al. 2015). The Trends in International Mathematics and Science Study (TIMSS 2019), Martin, Davier & Mullis (2020) report that despite the abundance of ICT resources in schools, mathematical achievement of South African learners remains unimpressive. This does not mean that ICTs are not important in teaching and learning. Indeed, as the National Council of Teachers of Mathematics (NCTM 2000:24) argue, 'Technology is essential in teaching and learning Mathematics; it influences the Mathematics that is taught and enhances students' learning'. The use of technology supports 'higher-order thinking skills, student achievement and self-efficacy' (Cullen, Hertel & Nickels 2020:66). Thus, every opportunity must be used to teach Mathematics with technology as it enhances conceptual understanding in much deeper ways. I reiterate that while all agree to the potential of technology to further the teaching and learning of Mathematics, a great chasm exists as to how to get there.

This research embarks on such a journey to explore how teacher educators and their students explored ways to navigate this chasm at a time when f2f teaching was no longer possible during the COVID-19 lockdowns.

Research questions

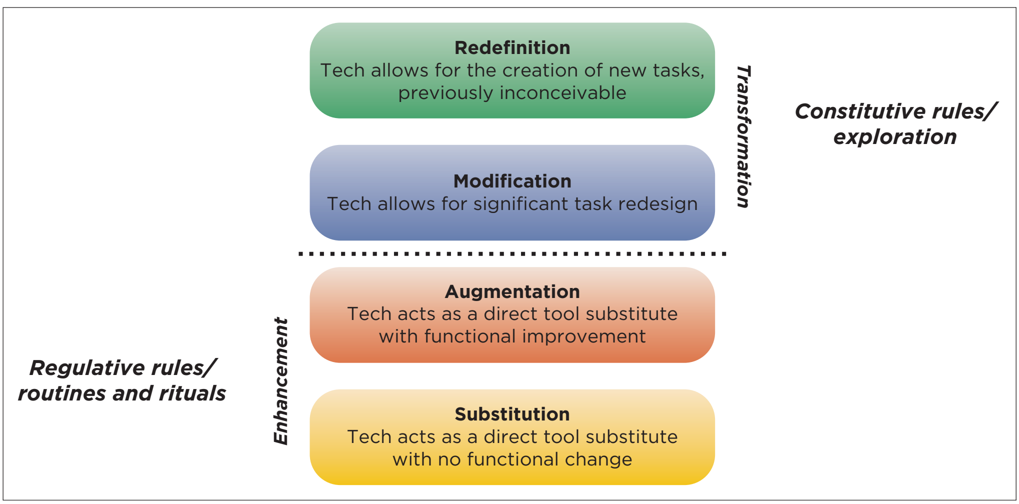
1. In relation to the SAMR model (Bray et al. 2013), how do teacher educators use ICT resources to teach Mathematics online?
2. What constraints and affordances do ICT resources avail in mathematics teacher education?
3. What mathematical PCK does this research report on online teaching and learning of Mathematics for teacher educators?

Theoretical framework

Granted that learning is a gradual process sustaining humanity (Vygotsky 1978), to what extent and what theories may refer to effect this change when ICT tools are used? The use of technology in teaching Mathematics can be viewed from the sociocultural perspective, where learning is psychologically mediated by signs and tools (Vygotsky 1978). The signs and tools mediate psychological activity to enhance meaningful learning first in the inter-psychological plane and then in the intrapsychological plane. However, on the pedagogical side, ongoing research suggests that there is specialised CK for teaching Mathematics, which knowledge is critical to the work of teachers of Mathematics (Ball, Thames & Phelps 2008). While the seminal framework by Ball et al. (2008) operationalises PCK through the teaching and learning of Mathematics on the ground, it does not take into account the TPACK (Koehler & Mishra 2009) necessary to harness technology to enhance the teaching and learning of Mathematics.

The SAMR model (Bray et al. 2013) (Figure 9.1) seems more appropriate, as it explains the various stages and evolution of technology use in teaching and learning. The first stage is where technology simply substitutes traditional teaching roles such as giving texts, workbooks and exercises – hard copy transformed to soft copy –but rapidly shared online. This is the stage where most teachers in South Africa are. Then there is augmentation, when technology is used for functional improvements, such as direct learner feedback to tasks, which improves participation. In the modification stage, common tasks are accomplished via technology and there is more participation from students among themselves as they share knowledge. The highest stage is the redefinition stage, where previously inconceivable tasks are availed by technology.

Thus, the SAMR model shows the transformation of use of technology from rituals and routines to explorations (Sfard 2016) which lies at the heart of learning.



Source: Adapted from Bray et al. (2013) and Searle (2018) Regulatory and Constitutive Rules (Searle 2018).
Key: SAMR, substitution, augmentation, modification and redefinition.

FIGURE 9.1: The SAMR model.

TABLE 9.1: Characteristics of the substitution, augmentation, modification and redefinition model.

Level	Definition	Examples	Functional change
Substitution	Computer technology is used to perform the same task as it was carried out before the use of computers	Teachers or students print out worksheets and pass them on	No functional change in teaching and learning. There may well be times when this is the appropriate level of work, as there is no real gain to be had from computer technology.
Augmentation	Computer technology offers an effective tool for performing common tasks	Students take a quiz using a Google Form instead of using pencil and paper	There is some functional benefit here in that paper is being saved, while students and teachers can receive almost immediate feedback on a student's level of understanding of the material. The impact of immediate feedback is that students may begin to become more engaged in learning.
Modification	This is the first step over the line between enhancing the traditional goings-on of the classroom and transforming the classroom. Common classroom tasks are accomplished through the use of computer technology.	Students are asked to solve Mathematics problems and record how they solve them. The recording will be played in front of an authentic audience, such as parents.	There is a significant functional change in the classroom. Computer technology is necessary for this classroom to function, allowing peer and teacher feedback. Mathematics questions increasingly come from the students themselves.
Redefinition	Computer technology allows for new tasks that were previously inconceivable	Students are to investigate, cooperate and collaborate, solving authentic problems with the aid of technological tools	At this level, common classroom tasks and computer technology exist not as ends but as supports for student-centred learning. Questions and discussions are increasingly student-generated.

Source: Adapted from Bray et al. (2013).

Gardner's multiple intelligences theory

Gardner's Multiple Intelligences Theory (2011) proposes that human beings possess different talents. It proposes that there is no single definition of intelligence, namely that traditionally measured by intelligence quotient. He argued that there are different types of human intelligence. This means that different learners would process information differently depending on their intelligence orientation. He proposed the different types of intelligence. The first is 'verbal-linguistic intelligence', where learners will learn more easily via spoken and written language. The next type of intelligence is 'logical-mathematical intelligence' related to ease with doing and solving mathematical problems. Then there is 'visual-spatial intelligence', which allows such learners to deal with spatial information more easily. Other types of intelligence are musical and naturalistic intelligence related to biological and other scientific knowledge, bodily-kinaesthetic intelligence related to the use of one's body, such as in sports and interpersonal intelligence related to the power to understand and empathise with other people's internal conditions such as desires and motivations. This intelligence is related to diagnostic knowledge. Lastly, there is intrapersonal intelligence referring to a person's capability to understand themselves. It would appear that people with interpersonal intelligence and intrapersonal intelligence can be charismatic leaders.

Gardner emphasises that everyone has these types of intelligence but that different people tend to have varying strengths towards some type of intelligence.

Why is this theory important to ICT in education? Gardner's (2011) theory is important because ICTs, through their ease and capacity to use multiple mediums of communication, can cater for the different intelligences and learning styles of different learners. ICTs have the capacity to individualise learning which is argued for by the multiple intelligences theory. Combined with the SAMR model, we see very powerful theoretical lenses to study the use of ICTs to reach different learners in teaching and learning Mathematics.

Literature review

Cullen et al. (2020:66) highlight the four main enhancements of digital technologies in mathematics education. These are, firstly, promoting cycles of proof (i.e. explore⟵⟶conjecture⟵⟶test/revise⟵⟶prove), secondly, presenting and connecting multiple representations, supporting case-based reasoning and finally serving as a tutee.

To Cuoco and Goldenberg (1996:15), technology is most helpful 'to help students gather data and to test, modify and reject or accept conjectures as they think about these mathematical concepts and experience mathematical research'. Technology is also particularly helpful in producing multiple representations of mathematical ideas, for example, in drawing graphs. This way learners can explore patterns and phenomena, such as keeping one variable constant and changing others to investigate what remains constant when other variables change. This way, some errors and misconceptions are quickly allayed.

Cullen et al. (2020:67) agree with Sfard (2016) that authentic activities help learners do explorations in Mathematics which is its learning goal. Authentic activities help learners to explore Mathematics in deeper and more meaningful ways and technology becomes a handy tool for mediating that learning. Notwithstanding the advantages of technology in learning Mathematics, there is always the danger that learners may focus on the technology itself or use it for other purposes and thereby lose the Mathematics which is the *raison d'etre* of all this effort.

Research design

Methodology

This study was qualitative as it focused on the interpretation of the coping practices that helped teacher educators to deploy digital technologies to augment or forgo traditional teaching methods, modify and redefine teaching and learning (Bray et al. 2013) in the face of virtual learning forced upon them by the COVID-19 social distancing limitations.

Microsoft Teams interview data on the challenges participants faced with digital technology-based lectures as well as affordances and constraints the technology availed them and their students were collected. The sample consisted of mathematics teacher educators, of whom three were female lecturers holding PhDs and one was a professor, as well as eight male lecturers who were PhD graduates and three were professors. Staff experiences in teacher education ranged from one year to 35 years and their levels of use of digital technologies were varied. The staff taught undergraduate teacher education Mathematics and mathematics methodologies courses. A few more experienced staff members taught at honours and master's levels. All staff supervised research projects at different levels from honours to PhD.

For several years, the university has been using the Sakai online LMS. In 2021, it adopted to Canvas-Ulwazi LMS. While these systems offered extensive support for online teaching, the resource uses are largely unexplored. This research, among others, explored to what extent the mathematics teacher educators used these resources and others to find out how these could optimise students' mathematical cognition.

As with all research in this institution, appropriate ethical clearance protocols were obtained and adhered to protect participants' privacy and unanticipated harm.

Data analysis

Many universities have in-built online teaching and support LMSs such as Sakai, Moodle and Canvas-Ulwazi. Teacher educators have these at their disposal. These enable them to manage teaching and learning such as communications, delivering lectures, issuing assignments, as well as marking and expeditious feedback to their students.

Data from mathematics teacher educators indicate that these online systems are the most used for lower levels of the SAMR model. While students' productions are possible on these online systems and can be facilitated, teacher educators have not, in the main, encouraged them. Some teacher educators believe that the transformative roles of digital technology education are time-consuming.

Experiences of teacher educators during lockdown

On being asked about their experiences of teaching Mathematics during the COVID-19 lockdowns, Netsai (a pseudonym) seemed to encapsulate what many of her colleagues referred to:

> 'The lockdown took me by surprise. Besides the health concerns the lockdown brought upon me and students, I did not know what to do in order to continue being

> in touch with my students. The university did provide us with new laptops as well as the capability to claim for Wi-Fi Data. However, as to what to actually do, I was at the deep end. Besides posting reading materials and daily exercises on Canvas, I also suggested YouTube videos for students to watch on particular concepts of the day. I did have interactive sessions later on using Big Blue Button and Microsoft Teams. However, student attendance and participation remains low up to today. This is one of the big problems of using digital technologies in teaching and learning. Participation is low. The idea that all lectures are recorded makes it worse because students say I will view the recorded lecture later in my own time.' (Netsai, female, date unspecified)

Netsai's concerns mirror the experiences of the majority of participants in that they were suddenly expected to continue delivering their courses using technologies they were not familiar with and had little or no training. As such, the level of technology use was at the substitution level of the SAMR model (Bray et al. 2013).

Information and communication technology facilitate differentiated instruction

Gardner (2011) proposed the multiple intelligences theory of how different learners learn. Gardner argued that different types of learners have different learning styles and therefore require different ways they are taught. Therefore, different learners cannot be fully catered for by the same teaching style.

For ICT mediation to be optimised, teaching and learning need to be strategic. It must be informed by detailed knowledge about students' current capabilities, misconceptions and what they need to learn (Makonye 2017; Tomlinson 2014). Gardner's (2011) theory is important in this regard because if the teachers appreciate their students' capabilities and strengths, they are in a better position to assign learners tasks as well as the appropriate computer tools to help mediate learning. ICT tools are varied, and learners can also choose by themselves which resources are most appropriate for their learning (Namome & Moodley 2021). Namome and Moodley reported that learners' chosen activities and online learning activities were more powerful antecedents to their learning than teacher-led online activities.

Information and communications technologies' multiple representations of mathematical concepts aid students' deeper understanding

One teacher educator gave this narrative on the affordances of digital technologies in mathematics education. The educator's explanation is given in this author's words in what the educator was referring to.

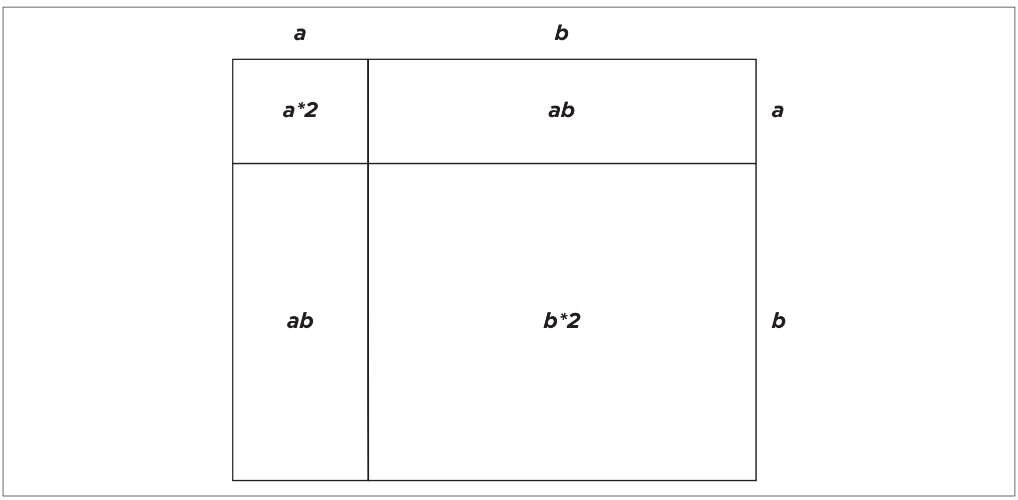
Online activities on the investigation if $(a + b)^2 = a^2 + b^2$ and what transformation can happen to $f(x)$ if the graph now becomes $f(x + 2)$. What, if any, is the relationship between these mathematical situations?

The educators suggested that learners might use calculators for different numbers for *a* and *b* and quickly realise the fallacy of their conjecture.

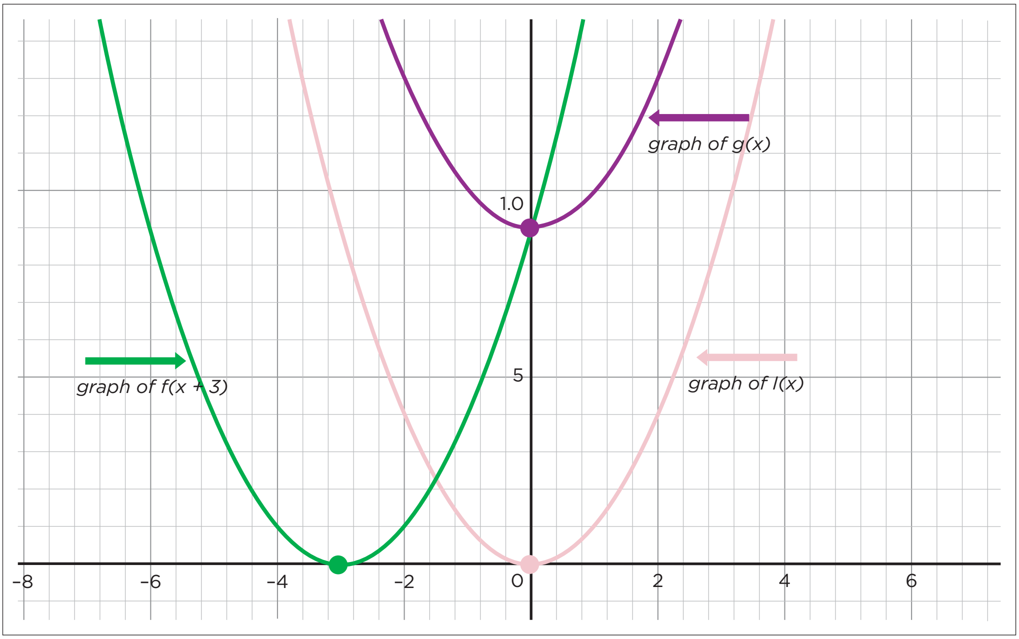
In addition, traditionally, drawing a square of side $(a + b)$ and using areas of rectangles therein settles the issue (Figure 9.2). Learners see for sure that the area $2ab$ has been left out in the conjecture $(a + b)^2 = a^2 + b^2$.

In the second task, a learner is asked what changes may happen if the graph of the function $f(x)$ is compared to that of $g(x) = f(x + 3)$. The surface and erratic interpretation is that the graph of $f(x + 3)$ is a shift of 2 units horizontally to the right of the graph of $f(x)$. This is a common learner misconception (Makonye 2017). Quick investigations with graphing computing technology, such as with GeoGebra will show and allay the mistaken assumption (see Figure 9.3). The teacher may then interview the learner why the graph $l(x) = x^2$ shifts 3 units horizontally to the left given $l(x) = x^2$ is symmetric on the *y-axis*. Such questions raise the sceptre of learning with computers rather than learning from computers. In this case, explorations enabled by technology begin to occur leading to a deeper grasp of mathematics knowledge. The use of digital technologies readily provides learners with impersonal cognitive conflict that challenges students to engage with the mathematical demands for learning. Technology facilitates proof and refutations of conjectures (Calvert 1999) that arise in the learning of Mathematics. For example, a learner might assume that in the graph of $f(x + 3)$, the graph of $f(x)$ will have been shifted three units horizontally to the right. Learners might want to use different examples to investigate that.

Or they may premise to investigate if $l(x) = x^2$, $f(x) = (x + 3)^2$ is the same graph as $g(x) = x^2 + 3^2$ that is $g(x) = x^2 + 9$.



Source: Author's own work.
Note: In the figure *a* * 2 refers to a^2.
FIGURE 9.2: Traditional square used to disprove the conjecture that $(a + b)^2 = a^2 + b^2$.



Source: Author's own work

FIGURE 9.3: Computer-generated graphs to disprove the conjectures that $(a + b)^2 = a^2 + b^2$ *f(x)* and *g(x)* and that *f(x + 3)* is a horizontal shift of *f(x)*, 3 units horizontally to the right.

Investigations through computer-generated visual representations of this nature are critical in building students' procedural and conceptual knowledge. Such investigations are readily available through the use of digital technologies and are transformative rather than substitutive (Bray et al. 2013).

I analyse the mathematics educators' narration and report that from the horizontal mathematisation arising from the investigations of the misconception, $(a + b)^2 = a^2 + b^2$ can arise many other important vertical mathematisations.

From Figure 9.3 can arise the question for which values of x is $f(x + 3) > g(x)$? In effect the inequality; for which values of x is $(x + 3)^2 > x^2 + 9$?

The solution to this can just be read from the graphs, in which case the answer is x is greater than 0.

As much as digital technologies help with exploring Mathematics, the analytical processes of traditional Mathematics are still required to formalise mathematical knowledge to communicate it to others in the community of practice. When using mathematical routines, that is, procedures, the problem can still be solved:

$$viz\ (x + 3)^2 > x^2 + 9$$

$$x^2 + 3x + 9 > x^2 + 9 \qquad \text{[Eqn. 9.1]}$$

$$3x > 0$$

Whence $x > 0$, which confirms the solution from the graph. However, the algebraic solution needs to be foregrounded by explorations enabled by technology, as in Figure 9.3. This avoids the danger of using rules without reasons if the analytic solution is foregrounded rather. This example demonstrates the power that the computer tool can avail to promote a deeper understanding of Mathematics through explorations rather than just rituals.

This example shows that far from being nuisances in the learning process, learners' anomalies and uncertainties must be taken as conjectures for which online tools are readily available to offer representations that can be used to generate cycles of proof. Then learning Mathematics moves to the exploratory stage rather than rituals and procedures, where learners mimic teachers' worked examples to arrive at the correct answer and please teachers.

ICTs are important in that they provide students with numerous ways to access learning material and so enhance learning (Hattie 2011). Further, students can learn at their own pace. If lessons are recorded, students can access them at any time for learning support.

One of the most familiar but important uses of technology in teaching and learning is the use of video and multimedia lessons and presentations. These animate teaching and learning through visual effects, snapshots, videotapes and music, all of which cater for learners' multiple intelligences (Gardner 2011). There are programmes that facilitate conference calls such as Microsoft Teams, Big Blue Button, Zoom and Skype. These maximise fun in learning and learner engagement.

Further, ICTs allow students to use various opportunities to present the knowledge and skills they have learned. This is critical as such engagements help with multiple representations of the concepts and skills they have learned. Therefore, they formatively and summatively provide teachers with a much better view of what students can and cannot do (Darling-Hammond 2010).

Teacher educators reported that the use of ICTs in mathematics teaching and learning gave more freedom and autonomy to students' learning. Students had more self-directed and self-regulated learning.

With ICTs and the Internet, the world is an open classroom. Teaching and learning are no longer constrained to the four walls of the classroom, the textbook and the teacher. Learning is now possible 24/7 and one can learn from any teacher who posts videos or texts on the Internet.

Incorporating ICTs in teaching and learning enhances teacher-student and student-student communication. Also, speedy and more accurate communication between parents and school is enhanced. For instance, the use of calendars enables parents to know when students write tests and examinations. Students' performances on these can be shared in real time with parents. This empowers parents to support their learners. One of the most vital uses of technology in teaching and learning is that it gives expeditious feedback. In other ways, teachers marking of students' scripts is lessened. In Mathematics, solutions to mathematical problems are readily available. Therefore, there is a possibility for students to self-coach and be independent of the teacher.

Using technology in learning enhances obtaining timely feedback from students. This helps educators to determine what is working and what does not. This helps educators to intervene early on and address students' errors and misconceptions about curricula materials. Technology enables rapid online surveys and polls to ascertain students' attitudes, perceptions, knowledge and skills. Manshadi (2021) reports that apps as 'helping' affordances would help students maintain their focus on mathematical content and their learning process, while 'hindering' affordances would distract children from their mathematical focus.

In terms of regulative discourse, digital technologies have many clear advantages. For example, students can write solutions to mathematics tasks with a pen and pencil, and then they can photograph them and submit them on a canvas learning system. Educators can then mark them electronically, showing correct and wrong workings. Then they can award marks for the assignment, which will be captured electronically. Students can view their grades as soon as possible. Online systems are excellent at keeping students' records.

Solutions to mathematics tasks and associated memos can be loaded on the learning system and students can access them anytime, anywhere.

The major constraints reported by mathematics educators are that ICT usages in mathematics teacher education relate to the choice of teaching and learning apps. The educators reported that there is always the twin challenge that while educators already know the mathematical content and mathematical procedures they want to teach, they have to learn the technology. 'It is tautological to indicate that you cannot use a tool that you do not understand', Dr Daniels (a pseudonym) said.

In his own words, Dr Daniel (Mathematics lecturer) said:

> 'Digital technology in itself is a very specialised technical subject and it is too much to expect mathematics teachers to know too much of that knowledge ... further the changes in digital technology are so rapid. As a matter of fact, educators always face the challenge of using a tool that they do not fully understand. Also the main target of this enterprise is the learning of mathematics in which technology is just a vehicle to get there [...] There is always the danger that the focus on mathematics might be blighted by the focus on technology.' (Dr Daniel, male, date unspecified)

I report that this is one reason why some sceptics have resisted the use of technology because they believe that using technology in the teaching and learning of Mathematics affects the attention on Mathematics. Also, it puts an extra burden on teachers and learners. In this case, there is the worry that teachers and learners will have less time to learn Mathematics.

Fanuel said, 'The prevalence of the Internet increases the possibility of cheating on assessment tasks. Virtually all mathematics tasks can be Googled, and many solutions found'. Fanuel's comments indicate an important setback in using the Internet for assessing mathematical achievement. It is incumbent for educators to devise authentic mathematics tasks which do not readily ask for mathematical procedural knowledge. These tasks are open and require interpretation and coding by the students before learners can use technology to investigate the phenomena or help with the mathematics procedures. Further, it might be helpful that assessment of learning still takes the traditional sit-in examinations to avoid problems of cheating that the Internet readily facilitates.

The teacher educators Patricia, Peona and Patrick indicated that educators work in isolation and have little support in using digital technology in teaching and learning Mathematics. In learning to use technology for teaching and learning, the teacher educators reported that they have to invest a great deal of time in developing basic competencies and skills. For example, many teachers have heard about the GeoGebra app for teaching Mathematics, but the majority have no idea of how to use it in their teaching.

This research suggests that an educator's awareness of the multiple intelligences (Gardner 2011) that emphasise the individuality of learners and their learning styles is critical in allocating them the tasks and ICT tools they can use in learning. In particular, the 'knowledge of students' (Ball et al. 2008) is critical in ICT deployment for learning. It is clear that the knowledge of students, knowledge of mathematics content and specialised CK in themselves are not enough. What is important is diagnostic knowledge (Tomlinson 2014) as well as knowledge of technology. Once an educator understands their learners' levels of understanding as well as their bearing on learning, the next step is to choose suitable mathematics tasks for the learners to engage with so that they can gain the knowledge referred to by Sfard (1998) as the acquisition metaphor as opposed to the participation metaphor for learning.

Discussion

When used optimally, one of the best effects of technology is to improve cooperation and collaboration among teachers and students, students and students and other stakeholders. Digital technology plays a key role in semiotic mediation in the teaching and learning of Mathematics. It helps students to link between different mathematical representations of mathematical concepts, *viz.,* verbal, visual, numeric, algebraic, graphical or abstract. That way, technology can individualise learning and thus cater for learners' multiple intelligences and learning styles. For technology to support student learning in this way, it must be strategically adapted in the classroom. This research found that this is the greatest challenge for mathematics teacher educators. It might be important for educators to pick one or two computer applications and consistently use them for some time. They adapt and adopt them in their mathematics teaching. This may be quite difficult for educators, given the mirage of computer apps available out there on the Internet. Most of these apps are not created by teachers, per se, but are commercially driven entrepreneurs. It is hoped that if educators and learners thoroughly understand and use one or two chosen applications, it will make them versatile and able to use newer apps in mathematics teaching and learning.

One of the main drivers of learning is learning by exploration rather than learning routines being the use of real-life problems in learning Mathematics. The use of real-life contexts, as in realistic mathematics education (Freudenthal 1973), is key in motivating students and teachers to harness technology as a tool in mathematics problem-solving on problems that are of immediate and captivating interest to them. This arrangement helps students to construct their own mathematical knowledge (Manshadi 2021) in a social space. In using technology in mathematics teaching and learning, we consider the work of Calvert (1999) on mathematical practises in that computers are harnessed in as part of generating, investigating, proving and disproving mathematical conjectures.

■ Conclusion

Technology has greatly impacted every section of society, including education, and this impact is set to deepen. This study has shown that in mathematics teacher education, there are inroads of technology use mainly on the substitution and regulation discourse levels. For example, students living hundreds of kilometres from their tutors can be issued mathematics tasks. They can write them on paper, photograph them and submit them. Teachers can mark them electronically and give immediate feedback. Moreover, the records of all these educational transactions can be kept perpetually and can be revisited anytime. Records of lessons taught can be viewed anytime for revision purposes by both educators and students. Despite great affordances of technology in education, for example, catering for the individuality of students' interests and learning styles, vital checks and balances need to be put in place to control incidences of dishonourable practices. One way to overcome this problem is for curriculum designers to devise new mathematics tasks that do not openly call for procedures. If that action is taken, technology is used for a redefinition of mathematical tasks and how they can be learned.

At the transformative stages of using technology in education (Bray et al. 2013), it seems this is a grey area for mathematics teacher educators as few advances have been made at those levels. These are the levels where technology can be of great use in students exploring mathematical ideas. Many teacher educators report problems on the way to support constitutive rules.

Technology is inevitable and there is no way any educator can shield themselves from it. Although the study has shown that teacher educators are making inroads in using technology, they still need to acquire many skills and competencies. This will require that:

1. Teacher educators access continual PD in using mathematics computer apps such as GeoGebra. In this, it is also important for teacher educators to be informed which other mathematics computer teaching packages can be explored.
2. Best practice must be benchmarked. Schools and teachers who do well need to be visited. Educators can try to implement these in their own classrooms.
3. The Mathematics curriculum needs to be revisited so that more authentic mathematical problems are introduced, which can only be solved through the explorative use of computers to augment traditional mathematics tasks that are solved with the help of computers.

In conclusion, this research has shown that mathematics teacher educators are struggling to boost mathematics conceptual understanding at the transformative level of the SAMR model. Technology is being used to reach students, but the emphasis is on CAI instead of CBI (Young et al. 2018). Students are learning from computers instead of learning with computers.

Chapter 10

Improving students' understanding of geometry concepts through dynamic geometry computer software

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■ Abstract[13]

The chapter investigates how the use of dynamic geometry computer software enhances the students' understanding of geometry concepts. Generally, geometry is defined as the visual study of shapes, sizes, patterns

13. Sections of this chapter represents a substantial reworking of the following publication: Adelabu, Makgatho and Ramaligela (2019:52–63).

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and positions. The understanding of geometry is very important for students during mathematics experiences in school. For experiencing a well-rounded, independent and reasonably successful life, the knowledge of geometry is very imperative for students. Hence, it is important to motivate students to improve in understanding of the concepts. A total of 74 Grade 9 students participated in the research study. A quantitative method was used, and data were collected through a one-group pretest intervention and a post-test quasi-experimental method. The Geometry Mathematics Achievement Test and a Likert scale questionnaire were used as data-collection instruments. The result indicates that the dynamic geometry computer software has a constructive impact on the students' understanding and achievement of geometry concepts. The students also have constructive perceptions of the dynamic geometry computer software in terms of enthusiasm, confidence and motivation. The study suggests that mathematics educators should be trained further than basic skills in computer usage.

Introduction

Geometry is a very significant study in the field of Mathematics (Kutluca 2013; Özçakir 2013). Generally, geometry is defined as the visual study of shapes, sizes, patterns and positions. According to Bassarear (2012), it is the study of properties and relationships of shapes. It is a subset of the Mathematics subject which associates and interacts with culture, history, art and design, as well as strands of human constructs that allow opportunities to make a geometry lesson fascinating and exciting. Furthermore, geometry is commonly used to model real-world concepts, which has many applications in solving practical problems. Geometry is well-known in art, music and literature as it has a motivating antiquity of its own (Adrian 2001). It has a significant place in the expansion of philosophies and design. It can be used to inspire the development and use of conjecture, deductive reasoning and proof could be explained (Adrian 2001).

Learning geometry makes secondary students develop some basic skills which include logical thinking abilities; spatial intuition about the universe; comparing and generalising; being careful and patient, as well as reading and comprehension of geometrical concepts (Baki 2002; Kilic 2010; Kutluca 2013; Özçakir 2013; Suydam 1985). These basic skills help students' problem-solving skills with a series of techniques in both cognitive and behavioural approaches that can be applied in different fields which include but are not limited to art, architecture, engineering, robotics, astronomy, sculptures, space, nature, sports, machines and cars. The important cognitive component that students who are solving geometry problems should have is that they should first understand the composition of the problem. Students need to understand the facts, concepts and principles of the problem as well as the instructional method that can be used to obtain new knowledge (Ramlan 2016).

Geometry plays an important role in secondary schools' Mathematics curricula. According to the South African Department of Basic Education (DBE) (2011) geometry carries 30% of the Grade 9 Mathematics being taught in terms two and four. Grade 9 is part of the Senior Phase of General Education and Training (GET). GET is compulsory schooling for every student from Grades 1 to 9. Moreover, learners who successfully complete Grade 9 receive a GET certificate, which is level 1 on the National Qualification Framework (NQF) system of South Africa, before migrating to Further Education and Training (FET) Grades 10 to 12. There is a need to improve the students' understanding of this aspect of Mathematics. The reason for the improvement is that students learn the concepts of geometry to function effectively in the 3D world and to have a knowledge of concepts of point, line, plane, parallel and perpendicular. Students learn geometry to understand the basic properties of geometric figures related to measurement and problem-solving skills.

Numerous studies have indicated that teaching and learning geometry is difficult, although it provides numerous benefits to society (Bhagat & Yen Chang 2015; Luneta 2015). In South Africa, geometry is considered a problematic topic at the secondary school level (Van de Sandt 2007). Therefore, the poor performance in the subject can be traced to the understanding deficiency in the learning of geometry which discourages the students from learning.

The level of communication of geometry between teacher and students is very wide, and the reasoning level of the teacher is higher than that of the students, which brings incorrect ideas into the understanding of geometry (Lim 1992). Most mathematics teachers are not established in delivering instructions on geometry to the students because many teachers teach at a level which is different from students' level of geometric thought (Luneta 2015). Moreover, the procedure used in solving certain geometry problems is imperfect. As a result, students are very weak in learning which also results in the decline of the performance of students in geometry. In addition, the increasing dropout numbers at schools are the result of difficult topics such as geometry, as most students do not understand them well (DoHET 2013). Thus, various instructional materials should be adopted and applied to increase the understanding of geometry and genuinely capture the students' interest and imagination in Mathematics in secondary schools.

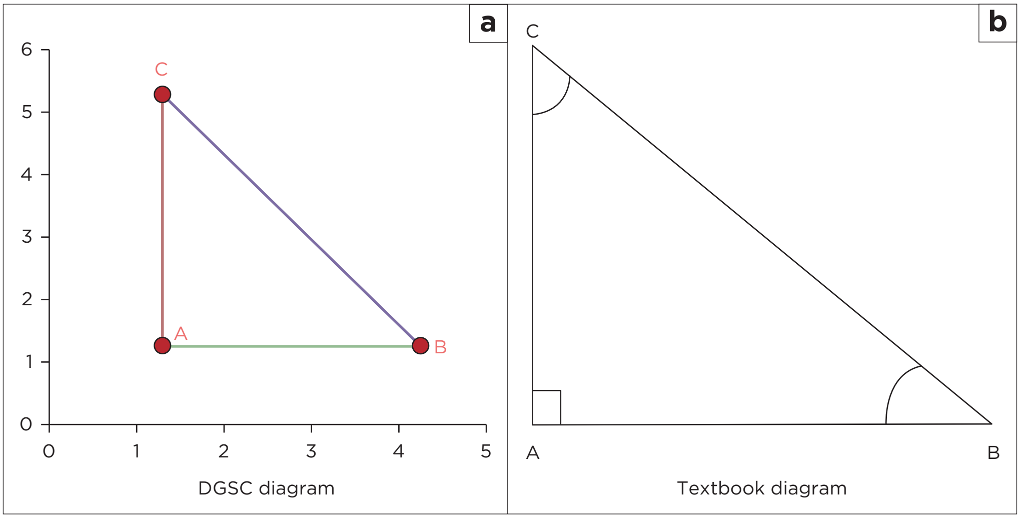
To adopt and apply 21st-century instructions, which are technology tools such as computers, interactive whiteboards and smart boards to teach in the classroom, integration of ICT is required. This means incorporating the use of computer-based communication into the classroom instructional processes. In this regard, ICT provides lively and proactive teaching and learning environment which will capture students' interest in Mathematics. According to Bester and Brand (2013), technology can be used to build on existing understanding to master new and more sophisticated content; therefore, it cannot replace the teacher in the classroom.

In the traditional method, geometry has been taught and learned with pencil and paper. Geometry textbooks in schools, especially in secondary schools, provide a representation of figures or shapes only with pencil and paper. Textbook-based illustrations may not be comprehensive because there will be no detailed visual description of a completely dynamic process that is needed for the construction of a geometrical concept (Denbel 2015). Dynamic visualisation of geometric shapes and figures is only a mental process in a textbook environment.

Textbooks show the ideal state (endpoint) of shapes and figures; to be more precise, students must create dynamic geometrical constructions in their minds in order to have more understanding of the concept. For instance, the illustration of points and line segments through drawings and diagrams are invisible objects viewed and imagined by the 'mind's eye'. As a result, students are compelled to look mentally into the possible properties of geometrical objects without an external way to increase their understanding of the related concepts (Denbel 2015). Therefore, students often fail to develop insights into the taught concept. Internalising the geometrical representations is a psychological challenge to the students in the pencil and paper environment, as it makes learning geometry difficult for many students (Mehdiyev 2009). This problem remains persistent in the teaching and learning geometry environment as it lacks dynamic features that may facilitate the justification and validation of definitions, axioms and theorems in a perspective manner (Mehdiyev 2009).

In order to supplement pencil and paper in teaching and learning geometry and to bring sincere interest and motivation on the part of students, as well as to develop their thinking and reasoning skills, a new environment was proposed by researchers (Flores 2002; Hohenwarter & Jones 2007; Laborde 2001). The authors suggest that the use of technology improves the students' understanding and therefore recommend a dynamic geometry environment for teaching and learning (Ding & Jones 2006). Dynamic geometry computer software (DGCS) has the capacity to make substantial improvements in teaching and learning geometry. Therefore, understanding geometry concepts requires a new way of delivering the concept. The understanding of the concept will offer a base from which students develop insights into the geometry concepts and ideas and skillfully apply them in solving problems. Hence, teaching and learning Mathematics with the technology tool will help the students to understand the concept.

Figure 10.1 (a and b) shows the triangle drawn with DGCS and a freehand triangle.



Source: Author's own work.
FIGURE 10.1: Triangle from (a) dynamic geometry computer software and (b) textbook.

Literature review and theoretical framework

Information communication and technology usage and benefits in teaching and learning Mathematics

To make mathematics instruction more dynamic, computers are tools that can be used to improve learning environments. Therefore, the integration of technology in ICT education is mainly performed by using computers in the learning environment (Akgül 2014). Computers (technology) contribute and provide support to individuals so that they can successfully accomplish daily tasks, which include complex tasks. The use of computers provides wide-ranging opportunities for enabling, supporting and inspiring mathematics learning in schools (Akgül 2014).

In South Africa, the integration of technology to teach at both primary and secondary schools has enhanced the students' accomplishment in Mathematics and some other subjects (Naidoo & Govender 2014). The enhancement is a result of the implementation of the *White Paper on e-Education* policy goal, which specifies that (DoHET 2004):

> [*E*]very learner in primary and secondary schools' sector should be ICT capable that is, use ICTs assertively and creatively to help develop the skills and knowledge that is needed to achieve personal aims and objectives and to participate fully in the global community. (p. 17)

In South Africa, ICT applications and devices such as power point applications and mobile devices, YouTube, game videos, multimedia, interactive whiteboards and smart boards have been integrated in some schools to improve the students' performance in Mathematics and other subjects. Integrating ICTs in schools augments the teaching and learning practices. It also makes the students ready for the workplace as ICTs are becoming more important (Chigona, Chigona & Davids 2014). The presence of computer software in the curriculum inspires productive learning as the students' thinking can be technologically advanced in a more effective way than in traditional teaching practices (Bester & Brand 2013). It helps students to develop a higher-order of skills, such as cognitive and critical thinking skills. ICT is also used to create learning environments and it supports an ideal learning environment which was impossible to achieve in the past (Chigona et al. 2014). Research shows that competencies such as understanding and problem-solving are better learned using interactive media such as dynamic computer software in teaching and learning (Bester & Brand 2013; Chigona et al. 2014). Using computer software in teaching and learning also assists the students in developing cognitive skills, critical thinking skills and information-accessing abilities, as well as evaluation and synthesising skills (Bester & Brand 2013; Chigona et al. 2014). Information communication and technology can also provide fast and accurate feedback to students (British Educational Communication and Technology Agency [BECTA] 2003). Hence, computer software is important and can be used to create a learning environment that supports the learning of Mathematics.

Teachers need to be self-assured and capable of using various ICT tools to build their belief in the technology. Therefore, they need experience and mastery of skills in integrating ICT in the classroom for appropriate instructional delivery. Consequently, teachers should have a variety of technical and communication skills, including using chat rooms, word processing skills, web page authoring and using various kinds of ICT tools such as file transfer protocol, compressing and decompressing files as well as computer software to deliver their instructions (Ghavifekr et al. 2014). Teachers' readiness and development are imperative to integrate ICT in teaching Mathematics. Teachers need to be ready and developed with effective ICT training to use computer software to teach their concepts (Moodley 2015). Ndlovu and Moll (2016) asserted that there is a need for teachers to initiate the integration process of ICT in learning by controlling the growth at which teachers and learners play their roles so that learning takes place in the classroom.

In education, Mathematics is an important subject to learn, the reason being that the subject has many benefits both in real life and in integration with other subjects (Milaturrahmah, Mardiyana & Pramudya 2017). Mathematics is a significant subject that can be integrated with various disciplines such as science, social studies, art, health, reading or language arts and physical education (Milaturrahmah et al. 2017). In this 21st century, Mathematics is a discipline needed to engineer new ICTs and a model to make new scientific discoveries. To have a successful solution to problems in the contemporary world, compact mathematical thinking is required. The integration of ICT is a way of engaging students in real-world problems, promoting recall and enhancing knowledge transfer. In this regard, learning Mathematics is placed within meaningful contexts to promote the use of practical activities that link to real-world problems (Fitzallen 2016). Moreover, for economic growth in the 21st century, the workforce must have the skills of Mathematics, creativity, expertise in ICT and the ability to solve complex problems. Consequently, nations need to create an education system where there will be an improvement in students' understanding of Mathematics and computer (technology), to produce graduates with the required skills in the field. The idea of learning Mathematics in ICT education is very important in that students will more frequently apply the concepts of Mathematics in daily life. This will enable the students to be accustomed to solving mathematical problems in everyday life by thinking scientifically and using technology to obtain various information. One of the branches of Mathematics is geometry, which is all around us and part of our daily lives. Geometry provides tools to engage analytically with our everyday surroundings. Therefore, learning geometry in school gives students the opportunity to see the indispensable connections of geometry in Mathematics.

The use of dynamic geometry computer software in learning geometry

Dynamic geometry computer software allows users to construct geometric figures or shapes and to measure the variables of the shapes and determine their properties. Dynamic geometry computer software also allows the users to drag the figures through the screen, make geometric constructions and explain the facts about these constructions as well as test them so that the user will generalise the facts. The expression of DGCS is the common name of unusual geometry software such as Cabri geometry, Geometers' Sketchpad, Cinderella and GeoGebra. The DGCS provides a nontraditional way of learning for the students (Guven & Kosa 2008). The integration of DGCS in learning geometry will enhance the construction knowledge in addition to the communication and dissemination of ideas in the geometry classroom.

The interactive learning environments of DGCS support the teaching and learning of abstract geometrical concepts in Mathematics. Dynamic geometry computer software makes students think independently, thereby allowing teachers to act as facilitators and only assist students when encountering problems (Naidoo & Govender 2014). Furthermore, DGCS offers new tools that go beyond the traditional method of teaching, so it widens the range of accessible geometrical constructions and solutions. It can be used for the visualisation of objects and enhancing the discovery learning process by enabling students to explore many more examples on the computer screen than what is feasible with pencil and paper. Additionally, DGCS enhances and promotes the students' understanding and achievement in teaching and learning of geometry, but when used alone it cannot improve performance (Nelson 2018). Hence, the DGCS offers new instructions that are far from traditional methods and extends the scope of availability to geometrical constructions and solutions.

Van Hiele theory of geometric thought

The theoretical framework that underpinned this chapter is the theory of Van Hiele's geometry thought. Van Hiele (1999) claims that students develop their knowledge of geometry in accordance with levels. The levels describe how the students' think and what type of geometric ideas they think about rather than how much knowledge the students have:

- **Level 1 – Visualisation or recognition:** In this level, students identify the geometric figures by their appearance but not based on their properties. For instance, a rectangle is 'something that looks like a door' and not a figure with four sides and four right angles.
- **Level 2 – Analysis:** Students analyse the figure in terms of the figure's components and properties. Students cannot tell the difference between the essential and adequate defining properties of a shape and the additional properties of a shape.
- **Level 3 – Informal deduction or abstract:** In this level, students logically interrelate the previously discovered properties and rules by giving informal arguments. Students can understand and form abstract definitions, distinguish between necessary and sufficient conditions for a concept and understand relationships between different shapes.
- **Level 4 – Deduction:** Students can reason formally using definitions, axioms and theorems. They can construct deductive proofs starting from the givens and produce statements that ultimately justify the statement they are supposed to prove. It is at this level that a typical secondary school geometry topic is taught.
- **Level 5 – Rigour:** Students establish the geometry theorems in different axiomatic systems and analyses and compares the systems. Nevertheless, in this chapter, the research only focused on the first three levels (Van Hiele 1999).

The model encourages students to build up concrete thinking from visualisation to analysis level and the ways of solving problems that involve finding solutions in Mathematics and real life. Therefore, students make new discoveries through visualisation and imagination, which helps the students to build a new concept of geometry via exploration through computer software.

Research problem

Despite the significance of geometry, studies discovered that it is difficult for students to understand the concepts of geometry in the classroom because of lack of proof by students, lack of background knowledge, poor reasoning skills in geometry, geometric terminology comprehension, lack of visualising abilities, teachers' method of teaching, nonavailability of instructional materials or gender differences, among others. Because of these reasons, students had been recording poor results in their final examinations, and they were unable to pursue valuable courses in HE and colleges. The purpose of the study is to investigate how DGCS integrating into the teaching and learning of mathematical geometry (congruent triangle) enhances students' understanding. This (DGCS) brings motivation on the part of the students towards geometry and they develop an adequate understanding of geometry concepts, geometry reasoning and geometry problem-solving skills. The objective of this study is to find out the understanding of the students and their perception after using DGCS to learn the concept of geometry.

Research questions

The following research questions guide the investigation:

- What is the mean score of the students' understanding after using the DGCS tool to learn geometry concepts?
- What is the students' attitude to the use of the DGCS for learning geometry?

Significance of the study

As revealed in the research problem, students had been recording poor results in their final examinations. Therefore, to deal with this low performance in Mathematics among students, this study sought to contribute to the literature by discovering another way of teaching geometry by using DGCS as the integration of technology. This is to motivate students towards geometry and help them to develop an adequate understanding of geometry concepts, geometry reasoning and geometry problem-solving skills.

Research design

Methodology

The study employed a quantitative approach with the use of a quasi-experimental research design. The one group's pretest intervention and post-test quasi-experimental research were used because the participants were not randomly selected. The difference between pre and post-test determines whether the DGCS influences the students' understanding of geometry concepts.

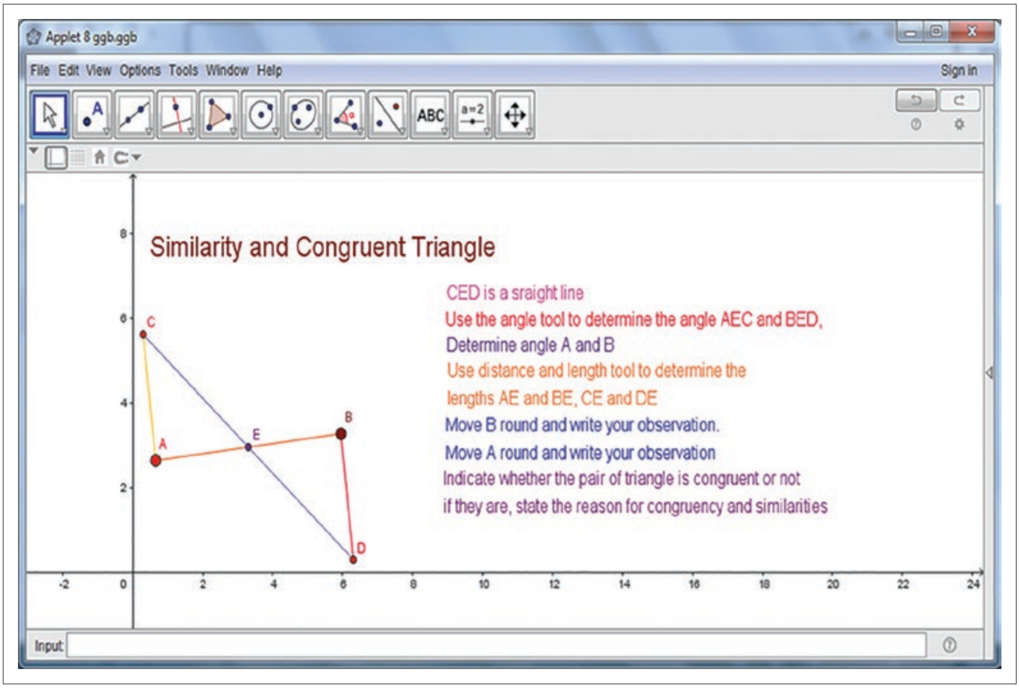
Research procedure

The study was conducted in Tshwane South district, Gauteng province, South Africa. Two schools were selected conveniently and purposively because of the availability of computer laboratories. A total number of 74 Grade 9 students were purposively selected out of the population of 319 students in the two schools. The instruments used in this study were the Geometry Mathematics Achievement Test (GMAT) and a set of questionnaires. The GMAT was used to compare their understanding before and after the use of DGCS. The test consisted of 15 multiple-choice items. The GMAT test was used to test the students' understanding as well as their geometry thinking in mathematical geometry. All students in the group wrote the test. The time allocated for the test was 30 min. The questionnaire comprised 15 items using a Likert scale of 1 – strongly disagree, 2 – disagree, 3 – unsure, 4 – agree and 5 – strongly agree. The questionnaire consisted of statements which reflected the student's perceptions of the use of DGCS. The study was analysed using both descriptive and inferential statistics.

The experiment

The groups were taught geometry using DGCS by the researcher. The computer software used in this study is GeoGebra.

GeoGebra 5.0 was installed on the computers in the presence of the students. After a brief explanation of the philosophy of the software, the students were arranged to sit in pairs or individually, depending on the number of computers available in the laboratory. Subsequently, students followed the instructions of the teacher and applied them on the computer. The instructions were based on the introduction to GeoGebra and tutorials taken from official website of GeoGebra. After getting knowledge about GeoGebra, the students under the support of the teacher were encouraged to draw basic geometric objects. Students continued to familiarise themselves with some menu and toolbar functions and were able to draw some basic geometric objects such as triangles, rectangles, parallelograms and polygons. The students worked on the computers and used worksheets to write down their results and findings. They worked with the applets designed by the researcher in GeoGebra.



Source: Adelabu (2018).

FIGURE 10.2: Screenshot of sample activities on similarity and congruent triangles.

Prepared activities applets on similarity and congruent triangles were given to the students through the computer software (GeoGebra). They were guided to learn and ensure their understanding of these aspects of geometry. The pretest (GMAT) was administered to the students at the beginning of the experiment. The GMAT administered to the students was also a post-test, after the students had received lessons on similarity and congruent triangles through DGCS for two weeks. Both the pretests and post-tests were collected from the students, and a closed-ended questionnaire was also administered to them. The reliability of the instruments was established by using Cronbach's alpha coefficient. The study was analysed using both descriptive (item-level) and inferential statistics. The goal of this statistical analysis is to establish whether a difference between the pretest and the post-test is significant. The mean and standard deviation (s.d.) of individual items in the questionnaire were analysed for deeper insights into the perception of the participants of the use of DGCS.

A screenshot of sample activities on similarity and congruent triangles using DGCS is shown in Figure 10.2.

Findings

The GMAT and the questionnaire were then administered to the students after they had been taught. The following is the analysis of the data obtained from both the tests and the questionnaire.

Students' mean understanding score after using dynamic geometry computer software

As seen from Table 10.1, the t-test showed that there was a significant difference between the mean scores of the pretest and post-test of the group, that is t (72) = 34.12, p = 0.000 < 0.05. This means that there was a statistically significant difference between the understanding and performance of the students after the use of DGCS. The students understood the geometry concepts better when using DGCS. A review from Bulut et al. (2015) shows that the multiple representations with DGCS can enhance students' understanding of mathematical concepts.

As with the studies conducted by Shadaan and Leong (2014), Mthethwa (2015), Keskin (2016), Dijanic and Trupcevic (2017) and Ocal (2017), the results of this study also showed that the use of DGCS in the L&T process can give a very good impact in improving students' ability. The students' perception towards using DGCS for learning is shown in Table 10.2.

Students' perception towards using dynamic geometry computer software for learning

Table 10.2 shows the response of the students after using DGCS to learn the geometry concept. The table shows the highest mean, which is 4.17; it is the ninth item of the questionnaire, which stated, 'Using computer software increases my interest in Mathematics'. These students had never used DGCS before. This motivates the students to enjoy learning Mathematics. The lowest mean was 2.35 for item six of the questionnaire, which stated, 'I have difficulty with DGCS'. This shows that not many of the students were afraid of using DGCS. Based on Table 10.2, the overall mean was 3.62, which shows that more than half of the students agreed with positive statements about DGCS. From the results, the conclusion drawn can be that using DGCS can increase

TABLE 10.1: Results of the independent t-test on the pre- and post-test of the group.

Test	*n*	Mean	s.d.	*t*-value	DF	*p* (2-tailed)
Pretest	74	31.78	9.10	34.12	72	0.000
Post-test	74	45.83	10.63			

Key: s.d., standard deviation; DF, degrees of freedom.
Note: T-value significant at p < 0.05.

TABLE 10.2: Mean and standard deviation of the questionnaire.

Items	Questions	Mean	s.d.
1	I learn many things using DGCS.	4.01	0.89
2	I enjoy learning Mathematics using DGCS.	4.0	1.0
3	I learn Mathematics better when I am being taught by a teacher rather than computer software.	3.69	1.36
4	DGCS makes me think critically and creatively during the learning period.	3.77	0.99
5	I gain a better understanding of geometry using computer software.	3.91	1.04
6	I have difficulty with the DGCS.	2.35	1.31
7	I do not like using computer software to learn Mathematics.	2.45	1.53
8	Using DGCS helps me to deal with my difficulty in learning geometry.	3.62	1.31
9	Using computer software increases my interest in Mathematics.	4.17	0.98
10	I prefer to be taught by a teacher when it comes to Geometry rather than computer software.	3.26	1.42
11	The use of computer software improves my understanding of angles, congruency and similarities.	3.93	1.06
12	I gain a great deal from my fellow students and the teacher during the learning interaction.	3.66	1.13
13	Visualising and manipulating diagrams through the DGCS makes me know the answers to the questions faster.	3.76	1.04
14	I am confident in using the DGCS.	3.88	1.10
15	I like DGCS for the purposes of teaching and learning Mathematics in our school.	3.86	1.26
Total mean		**3.62**	

Key: DGCS, dynamic geometry computer software; s.d., standard deviation.

students' interest, confidence and motivation in learning geometry concepts. This result is in line with the studies conducted by Vasquez (2015), Lalduhawna (2015) and Kepceoglu and Yavuz (2016) that also concluded that the use of DGCS in learning geometric transformations increased students' motivation; enhanced their learning and achievement.

The contradiction in the students' perception in this study is that some of them preferred to be taught by the teachers. This is reflected in item 10, which stated that 'I prefer to be taught by a teacher when it comes to geometry than the computer software', where the mean is 3.26. This indicates that the role of teachers cannot be replaced by technology, as teachers are not only the facilitator in the classroom but also serve to guide, mentor and inspire students. This is in line with the finding of Bester and Brand (2013) that technology is an additional supplement required for teaching and learning, not to turn an exchange tool for quality teachers, as it cannot replace the teacher in the classroom. Hence, the objective of this study is to ensure that students' understanding was improved when learning through DGCS as a technology tool.

■ Discussion

Geometry topics involve understanding the principles and procedures to describe the given concept. Using the DGCS with students motivates them to learn geometry concepts very well. Results of the study showed that the software encourages the students and increases their understanding of similarity and congruent concepts. The test results showed that there was a statistically significant difference in the post-test of the students. Precisely, the use of GeoGebra as an intervention during the study improved the understanding of the students. Students appeared to be satisfied with the dragging of the figures but stuck to the basic software tools. Moreover, most of the students who used the DGCS discovered more understanding of learning similarity and congruent concepts according to the questionnaire results. The software enabled the students to check the accuracy of the method used to conclude their work on the computer screen which was a great accomplishment, and this could increase the retaining level of students. In addition, with the use of DGCS, students could return to the activity several times on the computer.

In conclusion, this chapter has shown that DGCS has a constructive impact on students' understanding and achievement in geometry concepts. The students also have constructive perceptions of DGCS in terms of enthusiasm, confidence and motivation. Students need an understanding of geometry in order to be able to recognise similarities and differences among objects. The understanding of geometry is very important for students during mathematics experiences in school. Hence, to experience a well-rounded, independent and reasonably successful life, DGCS motivates students to improve in understanding geometry concepts.

This software introduction should be to the mathematics educators so that students can explore the world of Mathematics in a wider sense and make the students able to think critically. Furthermore, to enable educators to use DGCS successfully in the classroom, the study suggests that basic skills and knowledge of computer use are important. Mathematics educators should be trained further than basic skills of computer use because additional provision and training are essential to adequately and assertively use DGCS. Mathematics educators should also make use of the software as often as possible so that students are encouraged to go beyond memorising formulas and instead grasp the geometry concepts. As a result, students can improve their understanding and enhance their performance in Mathematics.

The findings in this chapter served as the primary stage; therefore, to understand how DGCS affects the understanding of students in geometry concepts, there is a need for further studies with bigger data sets, which could accommodate more than 300 students within a duration of one year or more. In this regard, a full standard geometry test in other areas of the geometry concepts, such as three-dimensional shapes, could be used in at least eight schools for further studies.

■ Conclusion

In conclusion, this chapter has shown that DGCS has a constructive impact on students' understanding and achievement in geometry concepts. The students also have constructive perceptions of DGCS in terms of enthusiasm, confidence and motivation. Students need an understanding of geometry in order to be able to recognise similarities and differences among objects. The understanding of geometry is very important for students during mathematics experiences in school. Hence, to experience a well-rounded, independent and reasonably successful life, DGCS motivates students to improve in understanding geometry concepts.

The study suggests that basic skills and knowledge of computer use are important. Mathematics educators should be trained further than basic skills of computer usage because additional provision and training with continuous practising are essential to adequately and assertively use DGCS. Mathematics educators should also make use of the software as often as possible as a learning environment to teach the students to enhance students' understanding of geometry so that students are encouraged to go beyond memorising formulas and instead grasp the geometry concepts. As a result, students can improve their understanding and enhance their performance in Mathematics.

Chapter 11

Microsoft Excel: A promising tool for teaching basic descriptive statistics in initial teacher-training institutions

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Abstract

Technology has permeated today's society. The education sector is also not spared and, of late, has witnessed technology becoming increasingly available or integrated into teaching and learning in trying to enhance concepts taught as it has the capability of simulating and uncovering hidden concepts. This study is qualitative and used a purposive sampling method to establish the extent to which education mathematics lecturers in two schools of education in the Gauteng province of South Africa use Microsoft Excel in the teaching of descriptive statistics. The availability of computing devices in schools of education does not reflect those preservice teachers majoring in Mathematics who are exposed to learning statistics at FET phase. Microsoft Excel is a

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product of the Microsoft Office suite and is available on all computing devices. However, participating education mathematics lecturers indicated that they are facing challenges in teaching statistics using Microsoft Excel because of limited knowledge and skills. Freire's CP approach was adopted as it focuses on empowering students to be full participants and co-creators of knowledge based on their own experiences. The method thus bails out students from the 'banking system model', which considers teachers (in this case lecturers) as the fountain of knowledge to be independent thinkers. In essence, Microsoft Excel has the potential to augment the teaching of basic descriptive statistics and may be used for performing data analysis by preservice teachers studying at the FET phase. The study concludes by discussing the reasons for not using Microsoft Excel in teaching and learning basic descriptive statistics, the potential benefits and the value it may add to the subject content. Finally, the study recommends that the Mathematics curriculum planners should tap the opportunities Microsoft Excel offers in speeding up the understanding of descriptive statistics and provide necessary training if possible.

Introduction

There is a growing recognition of the use of digital technologies in education as they come up with more multifaceted uses than people previously conceived. In the field of human-computer interaction, both the hardware and software of computers play a significant role in helping human beings to achieve their work at ease. Generally, the use of technology has pervaded and disrupted the way we do things. Since time immemorial, mathematics teachers have been enjoying teaching Mathematics using the traditional methods which comprise the use of chalkboards and textbooks. A students' task is to patiently receive, memorise and repeat the contents of the teacher's narration. It is clear that this kind of education has been deeply influenced by substantial thinking, wherein knowledge exists independently of the students. However, the proliferation of computing devices and other smart devices has compelled the education system to incorporate these tools for effective teaching and learning.

To incorporate these devices requires continuous training as they change over time. The training can begin at the institutions where teachers are trained or on-job PD. Teachers must continue to learn new or additional mathematics software content, study how students learn Mathematics, analyse issues in teaching Mathematics and use new materials and technology (NCTM 2000:370). This suggests that preservice teacher preparation programmes should incorporate IT so that prospective teachers begin to view themselves as relevant to contemporary students that are techno-savvy, essential for continued effectiveness in a rapidly changing profession. The argument of this study is that the current training offered to preservice teachers in Mathematics rarely uses platforms such as Microsoft Excel software to teach simple descriptive statistics. Although the South African government seems to be advocating the use of technology in teaching learners digital technologies at an early stage, this pronouncement seems to be not taken seriously by schools of education who are preparing preservice teachers that should be compliant with the rapidly changing environment. Thus, this paper attempts to illuminate the potential that Microsoft Excel has with regard to learning descriptive statistics by preservice mathematics teachers. Statistics contributes to a small percentage of matric Mathematics curriculum in South Africa, of which all these statistics topics can be solved using Microsoft Excel. In South Africa, matriculation (or matric) is an examination board which assesses the final year of learner schooling and awards a qualification upon graduating. The certificate awarded can be used as the minimum entrance requirement to HEIs.

Descriptive statistics at the matric curriculum level

The statistics content information was obtained from the *Curriculum and Assessment Policy Statement (CAPS)* Grades 10–12 (2011) document, which specifies the following materials that should be covered in each grade per year:

- Grade 10 statistics topics include measures of central tendency (mean, median and mode), measures of dispersion (range, quartiles, interquartile and standard deviation) and plotting box and whisker diagrams.
- Statistics in Grade 11 include presenting data in ogives or cumulative frequency, box and whisker to identify outliers. In addition, learners are required to calculate the variance and the standard deviation.
- Grade 12 statistics require presenting data on scatter plots and investigating whether the data is linear, quadratic or exponential, including drawing the best-fit line. Learners are also required to calculate the equation of the regression line and the correlation coefficient to determine the relationship between the two variables.

By paying close attention to the matric syllabus (South Africa's final year examination board of high school), all the concepts are sitting in Microsoft Excel. Students can be exposed to another possible way that can be used to work out statistical problems. Although the curriculum does not specify or compel the use of technology (let alone the use of calculators) in education, lecturers can take the opportunities Microsoft Excel provides for solving statistical problems in a rather accurate and fast way. In addition, teaching them solving statistical problems using technology may be preparing them for a future that is already using technology

Using Microsoft Excel in working out statistics

Microsoft Excel has become the most recently popular and powerful software tool, and it has found its place in the business sector. However, it can be exceedingly vital in teaching and learning simple basic and advanced statistics (Salkind & Frey 2021). The current generation can learn statistics much at ease as they spend most of their time interacting with digital tools – the learning experience can easily be connected to their day-to-day living experience. Statistics is mainly about describing, organising and interpreting large amounts of data (Bryant 2021). Use of Microsoft Excel can be used to analyse such data with minimum time and with fewer errors.

Statistics is taught using formulas that are abstract and difficult to understand. The formulas frequently need to be proven, making it harder for students to grasp the concept. That is the nature of statistics. From my experience as a mathematics teacher educator, there is little evidence indicating that most schools in the developing world teach statistics using Microsoft Excel. Microsoft Excel is an application that is used for recording, analysing and visualising data. It is in the form of a spreadsheet. Microsoft Excel comes with in-built or embedded formulas to solve a particular problem. Mathematical equations are the simplest types of Microsoft Excel formulas. At the most basic level, these use standard operators like the plus sign (+), minus sign (−), slash or solidus (/), an asterisk (*) to add, subtract, divide and multiply, respectively. For complex mathematics equations, parentheses go around the part of the equation that should be calculated first. However, with the case of two schools of universities studied, they seem to be lagging with teaching statistics using technology. It is imperative that schools of education prepare its young people, who are already immersed in technology, not only for the fourth industrial revolution (4IR) but also for an unimaginable future, in which digitisation and AI play roles that are ever more significant in just about every sphere of life. Preservice mathematics education lecturers are the lifeblood of effectiveness in the classroom, and again, the well-prepared, well-versed and thoroughly supported teachers are the heart and soul of the curriculum and instructional strategies that can occur. Despite the affordances and the functions Microsoft Excel has, there is very little evidence from the literature mentioning that South African schools of education use Microsoft Excel in the teaching of basic statistics at the matric level. Preservice teachers leave these institutions with limited knowledge of teaching descriptive statistics using Microsoft Excel.

Literature review

The mathematics graduates leaving institutions of ITE every year join the teaching profession with limited knowledge and skill in using technology in the classroom. Teaching using technology is a threat to them and tears apart the confidence they have in their subject discipline. Thus, Hartsellet al. (2009) view confidence as the prerequisite for practising teachers to accept any new instructional strategies. At the same time, the South African government is calling for technocratic students that can harness digital technology for education. Also, interrogate technology critically for epistemological practices it promotes. The use of Microsoft Excel in teaching statistics has the potential to increase preservice teachers' knowledge in statistics. Statistics, as defined by Ali and Bhaskar (2016:662), is a 'branch of science that deals with the collection, organisation and analysis of data and drawing of inferences from the samples to the whole population'. Thus, statistical methods involve carrying out a study that includes planning, designing, collecting data, analysing, drawing meaningful interpretations and reporting the research findings. Most mathematics education students leave teacher training lacking the necessary IT skills to succeed in a quantitative analysis course, in which they are often expected to input, analyse and plot results of experiments (Rubin & Abrams 2015). The statistical analysis gives meaning to the meaningless numbers, thereby breathing life into lifeless data. To perform this task, students need to be very analytical and interpretive of the behaviour of data distribution. Microsoft Excel may assist students in visualising the behaviour of such data. Nonetheless, several graduating teachers leave their teaching institutions not ready to teach descriptive statistics using Microsoft Excel. The integration of digital technologies across the curriculum through the use of Microsoft Excel has the potential to prepare young people for the current digitised reality, as well as for the future.

Generally, most students at teacher-training institutions in South African contexts find statistics very challenging (Arends, Winnaar & Mosimege 2017). It is because the formulas used are complex and challenging to comprehend, and probability tables are confusing (Millar 2001). Microsoft Excel has most of the common statistical tests or formulas already built in. The users need to remember those formulas where and when these are used. Mathematics education lecturers may lead students to focus more on statistics and less on the mechanics of the software (Warner & Meehan 2001). Data entry and manipulation are often easier in spreadsheet applications than in specialised statistical programmes such as SPSS, SAS, R, Stata and many others. Microsoft Excel reduces abstract concepts to more real ones in statistics and other subjects (Chaamwe & Shumba 2016). Instead of using the very expensive statistical package such as Minitab or SPSS in teaching statistics, Microsoft Excel can be used as a basic start. The other advantage that Microsoft Excel has is that it may show different methods for calculating measures of the spread and central tendency. For example, to calculate the mean, in-built formula like = average ( ), or = sum ( )/N or = (A1 + B1 + ...)/N can be used. In displaying information through graphing, Millar (2001) noted that Microsoft

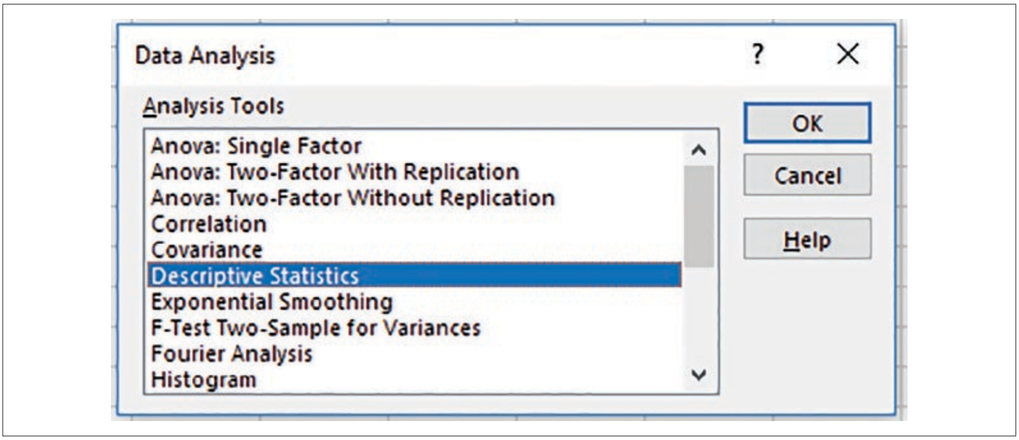
Excel plays a bigger part because graphing closely connects to statistical data, as the choice of graph is connected to the choice of statistical test. In view of Bell (2000), Microsoft Excel is an important tool in teaching statistics and has penetrated many spheres of the human work environment. For example, some students who are doing Master of Business Administration (MBA) benefit largely from Microsoft Excel, and it is against this background that we would like to see students that are doing mathematics education benefit equally from Microsoft Excel. According to Bell (2000), Microsoft Excel provides both immediate and lasting value as it provides quicker solutions. Students are likely to work in a future environment in which general software skills, such as the use of Microsoft Excel software applications, are expected (Warner & Meehan 2001). The students can use Microsoft Excel skills in other courses and are likely to have access to Microsoft Excel when they start work, and this provides a platform for them to improve their Microsoft Excel skills which may support their general problem-solving analysis skills. Similarly, preservice teachers can benefit in a bigger way by using Microsoft Excel to solve some statistical problems and it exposes them to the world that will be flooded by technology in the future. Bell (2000) noted the advantages that come with Microsoft Excel, such as:

1. being good for doing basic data analysis, including graphing and producing tables
2. has basic statistical functions (including average, standard deviation, median, slope, intercept) that are easily accessible through the 'function wizard (fx)'
3. generally, produces the answers statisticians expect.

Microsoft Excel has the 'Analysis Toolpak' that comprises data analysis tools, provides a great deal of more advanced statistical functionality making analysis of data extremely easy. Some of these analysis tools are shown on Figure 11.1. These tools can be accessed by clicking 'data analysis'. Paying closer attention to the Grade 10–12 basic statistics curriculum, the entire statistics is contained in Microsoft Excel. Statistics formulas in Microsoft Excel are much easier to follow than in basic statistics. When a formula is entered in Microsoft Excel, there are algorithmic steps that are to be followed.

Students are discouraged by formulas that they find difficult to interpret. For example, in regression analysis, students are required to calculate the correlation coefficient, r, to determine how closely data is in the scatter plot. Despite being given the formula, they have challenges in understanding what it means or what they are trying to achieve. R is calculated using the following formula:

$$r_{xy} = \frac{\Sigma(x_i - \underline{x})(y_i - \underline{y})}{\sqrt{\Sigma_{i=0}^{n}(x_i - \underline{x})^2 \Sigma(y_i - \underline{y})^2}} \qquad \text{[Eqn. 11.1]}$$



Source: Screenshot taken from Microsoft Excel by Alton Dewa.
FIGURE 11.1: Analysis tools.

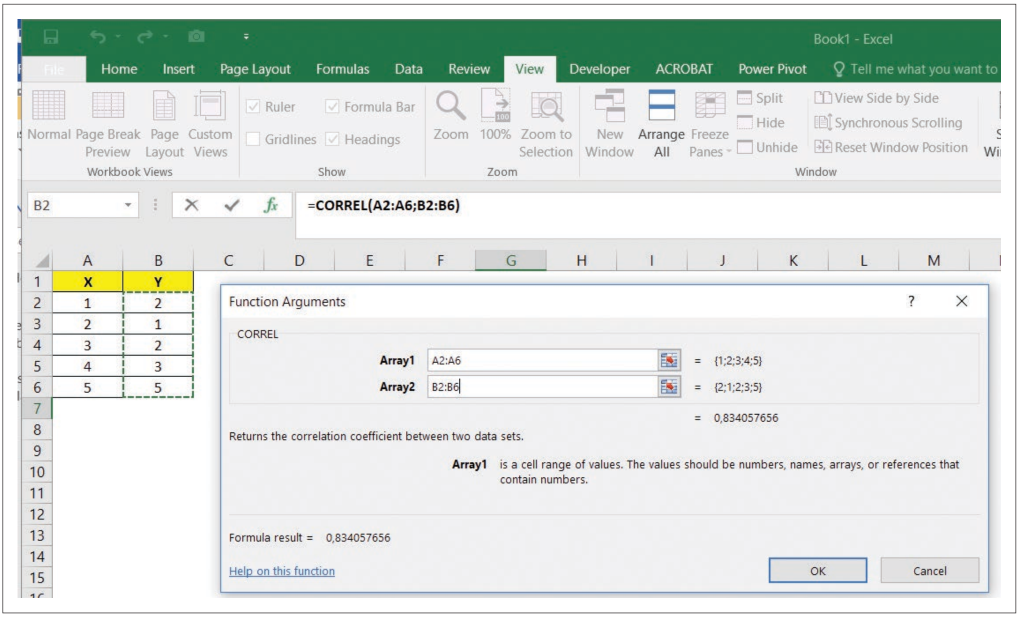
Where r_{xy} – Correlation coefficient of the linear relationship between the variables x and y; x_i – Values of the x-variable in a sample; $\underline{x}$ – Mean of the values of the x-variable; y_i – Values of the y-variable in a sample; $\underline{y}$ – Mean of the values of the y-variable:

$$r_{xy} = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma_{i=0}^{n} (x_i - \bar{x})^2 \Sigma(y_i - \bar{y})^2}} \qquad \text{[Eqn. 11.2]}$$

Where r_{xy} – Correlation coefficient of the linear relationship between the variables x and y; x_i – Values of the x-variable in a sample; $\bar{x}$ – Mean of the values of the x-variable; y_i – Values of the y-variable in a sample; $\bar{y}$ – Mean of the values of the y-variable.

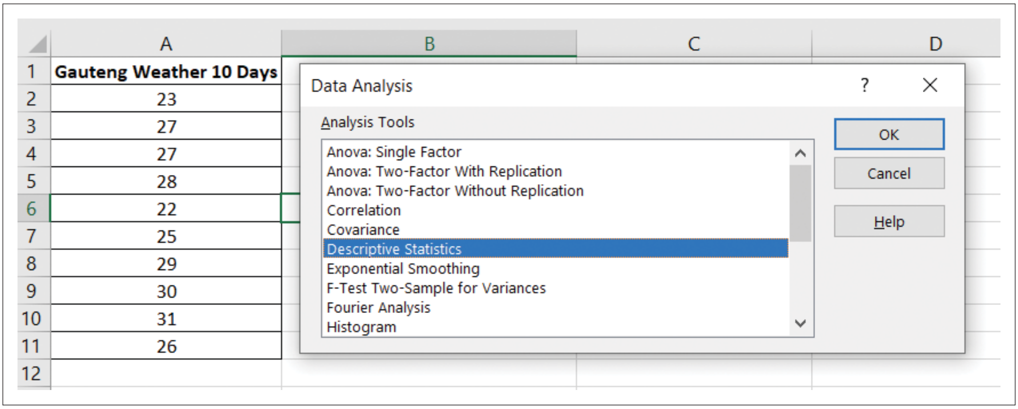
In most cases, students make many mistakes when capturing data into a calculator, resulting in incorrect information and, consequently, the wrong interpretation. However, in Microsoft Excel, there is no need to memorise the formulas; students need to know the function that can calculate the correlation coefficient, *r* (Correl), and then follow the prompt steps, as shown in Figure 11.2. Within a short space of time, they would have calculated the value of *r* and interpreted it based on the value displayed by *r*.

The Data Analysis ToolPak has an embedded descriptive statistics tool that provides an easy way to calculate summary statistics for a sample data set. The summary statistics include mean, standard deviation, median, mode, variance, skewness, range, minimum, maximum, sum and count. For example, Figure 11.3 to Figure 11.5 give a three-way step of displaying descriptive data for a ten-day weather focus in a particular city.



Source: Screenshot taken from Microsoft Excel by Alton Dewa.

FIGURE 11.2: Correl function.

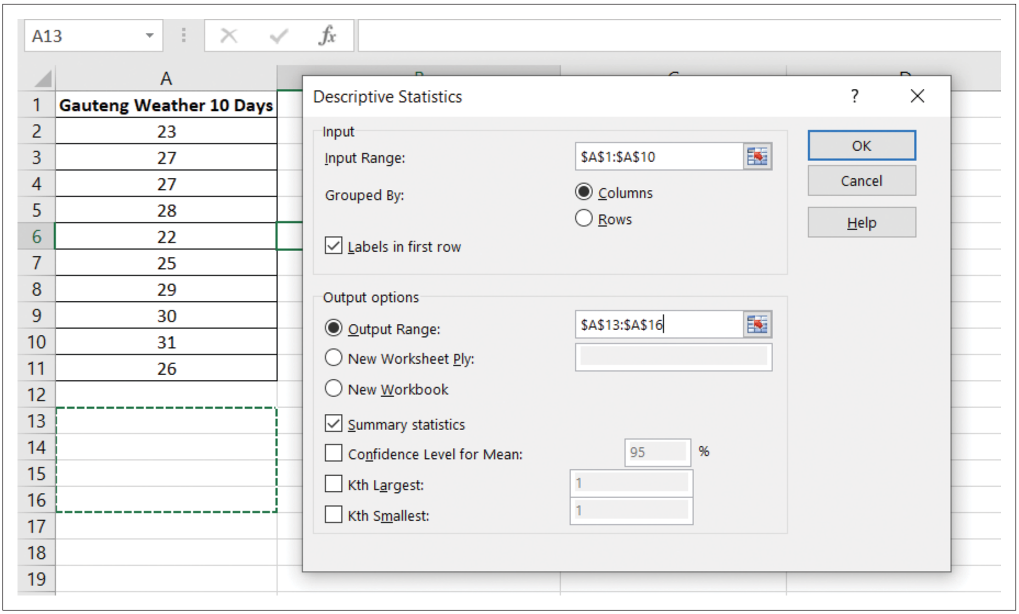


Source: Screenshot taken from Microsoft Excel by Alton Dewa.

FIGURE 11.3: Descriptive statistics for a ten-day weather focus.

In statistics, data can be viewed in a certain way. In some instances, we could be interested to see the average daily temperatures or the minimum or maximum temperatures, depending on what the data is needed for.

Generally, the Data Analysis ToolPak provides numerous ways in which statistical data can be analysed in Microsoft Excel using several statistical methods and operations. Microsoft Excel opens various teaching and learning platforms for students preparing to teach Mathematics in schools. As a result,



Source: Screenshot taken from Microsoft Excel by Alton Dewa.

FIGURE 11.4: Inputting of data in the fields.

Gauteng Weather 10 Days	
Mean	26.8
Standard Error	0.916515139
Median	27
Mode	27
Standard Deviation	2.898275349
Sample Variance	8.4
Kurtosis	-0.65287226
Skewness	-0.299849916
Range	9
Minimum	22
Maximum	31
Sum	268
Count	10

Source: Screenshot taken from Microsoft Excel by Alton Dewa.

FIGURE 11.5: Descriptive statistics values.

educators should take advantage of the educational benefits that come with this technological tool in order to prepare students with the data analysis skills that will be required in the future of work

Microsoft Excel affordances in teaching basic descriptive statistics

Microsoft Excel, sometimes referred to as 'spreadsheet', is a useful tool for dealing with most of the elementary probability topics taught in a typical statistics course (Nash 2007). It does well in sampling distribution. Graphing is accurate and clear and can easily be interpreted. Microsoft Excel is a ubiquitous application and thus is readily available for use by management and analysing data in the world of business and the government (Talha 2008). Undoubtedly, statistical calculations are performed using Microsoft Excel, and hence statistical education can take the advantages that it offers. Microsoft Excel can be used in producing frequency distribution tables, measures of central tendency and variability, median, percentiles and graphs (Duller 2008). Teaching statistics with Microsoft Excel is a bigger challenge among mathematics education lecturers, mainly because they lack relevant experience. Lack of experience is seen as the major hindrance in the use of Microsoft Excel in teaching and learning, leading to a lack of confidence and a general reluctance to integrate it in the classroom (Ang 2010). The use of Microsoft Excel in the teaching of statistics may be the bridge for the cognitive gap that hinders students from carrying out a statistical task (Ang 2010). Nonetheless, it should never replace mathematics education lecturers, but it should be viewed as a means of overcoming difficult concepts.

According to Mutsvairo, Ragnedda and Orgeret (2021:296), digital transformation 'requires a broader adoption of digital technology and cultural change'. The use of digital technology is 'dependent on both technology and people' (Nadkarni & Prügl 2021). What kind of technology can be used to solve a particular problem? Despite varying degrees and levels of digital technology affordances, the transition to digital education is about pursuing new ways of serving students. Thus, mathematical lecturers should consider the use of Microsoft Excel critically to help their students understand simple descriptive statistics. The use of Microsoft Excel in teaching descriptive statistics may help students develop cognitive domain, the skills involved in performing the tasks associated with perception, learning, memory, awareness, reasoning, judgement, intuition and language (Rollè et al. 2019). Microsoft Excel can facilitate engagement through interactive images embedded in it when simulating a scenario or a concept, thus enhancing cognitive development. Thus, the presence of digital technologies and digitalisation are essential in transforming the way mathematics lecturers teach statistics and should establish new effective ways of serving their students.

Critical pedagogy framework

The study adopted the lens of CP which advocates educational pedagogy that empowers students to participate and become co-creators of knowledge. Leonard et al. (2010) defined 'critical pedagogy' as a teaching pedagogy that focuses on addressing hegemonic practices that results in the marginalisation of specific groups of people. It seeks the educational approaches that emancipate students to be divergent through reflecting experiences in the societies that they are living in. This idea connects well with Bradshaw (2017:9), who mentioned that CP includes educational approaches that empower students to be 'full participants in democratic society through educational practices that are connected to learners' own experiences'. Undoubtedly, technology has permeated all aspects of our lives and is instrumental in the development of contemporary societies. The essence of CP pays close attention to day-to-day students' experiences and their realities. It attempts to uncover what works and what does not, as the students interact and experience the technological tools that work better to solve their daily lives. The generation of students at university are in the midst of technology; thus, they should be prepared in that direction. The statistics textbooks they are using have many formulas that present challenges for students to follow and give less for students to explore for themselves practically, a scenario that opposes the concept of CP. Critical pedagogy seeks to support the 'dynamic interactive elements' among the students, and as such it supports a view 'of humans and nature that is relational, an objectivity and subjectivity that is interconnected, and an understanding of theory and practice as coexistent' (Darder 2003:137). 'Critical education seeks to challenge, unmasking traditional claims that education provides equal opportunity and access for all' (Freire [1970] 2007:15–16). In light of this, critical theory attempts to challenge students' experiences and perceptions that shape the socio-economic realities that give meaning to how students define their everyday lives and how they construct what they perceive as truth. In addition, it could be said that CP claims that knowledge is created within the human historical context and it gives life and meaning to human experience (Darder 2003). The principle of ideology in CP serves as a starting point for asking questions that will help teachers to critically evaluate their practice (Giroux 2010). Teaching statistics using Microsoft Excel may emancipate students to think for themselves, as there is no need to memorise the formulas to solve descriptive statistical problems. Microsoft Excel provides some hints or syntax to be followed in solving the problem.

Critical pedagogy transforms the learning of the students from what they are experiencing in their lecture rooms and computer laboratories to their own contexts, which are predominantly technological. It allows students to move away from teacher-learner interactions into relationships of mutually supportive, engaged knowledge co-creators (Bradshaw 2017). It does alienate students from teachers but considers two parties working together to produce knowledge. According to Freire ([1970] 2007), teacher-learner interaction refers to transmitting knowledge to students; teachers are the ones knowledgeable, and students are considered as empty containers needing to be filled up. Teachers' role (seen as a storehouse of knowledge) is to deposit knowledge with the intention of withdrawing it later in the form of assessments. A banking model (Freire [1970] 2007) approach disconnects students from their own social realities and considers the students as compliant objects. The model perpetuates the traditional teacher-centred learning approach, which has lost its value in this era of the 21st century. Today's education mathematics lecturers should be critical and should challenge their own way of teaching approach and the needs of the students to avoid limiting potentials that may be realised (Aslan Tutak, Bondy & Adams 2011). Eventually, critical thinking may lead to critical consciousness, which in turn enables students to understand their lives in the terrain already dominated by the use of technology. Critical pedagogy in the use of Microsoft Excel in the teaching and learning of descriptive statistics may have a powerful impact on the student's success in the concepts, thereby building up their understanding of the subject. Students will have the ability and confidence to use and apply math practices and validate mathematical knowledge (Ernest 2002). The use of Microsoft Excel may help students make meaningful connections with the world and their everyday experiences. Consequently, it may speed up their cognitive thinking in solving concepts that they relate to in their everyday lives.

Central to the CP framework is that mathematics educators should attempt to influence knowledge that is relevant to the 21st century. Students of this century want to have knowledge that empowers them to solve complex problems with limited hindrances and need tools that will push their desire and experience to interrogate the problem at hand critically. Mathematics educators need to rethink how best they can offer the service that suits the 21st-century generation of students and refrain from being public intellectuals ready to solve social problems.

Research problem

Education mathematics lecturers play a pivotal role in preparing teachers that would be an asset to the country, teachers who would be participating in putting the country into the right economic direction and teachers who would be the agents of initiating change in the society that they are living in. They prepare these young and energetic teachers who can change the education landscape to be driven by digital technologies, the world that is driven by machine learning and robots. To achieve these ambitions, these education lecturers should be continuously trained and developed to up their skills in the use of technology. Therefore, PD is critical for these education lecturers to be relevant in contemporary classrooms. Knowledge and PD in the use of software may help them make some instructional changes in their classrooms. The research used the following research questions to achieve its objectives:

1. To what extent do statistics education lecturers utilise Microsoft Excel in teaching basic descriptive statistics?
2. How does the curriculum enforce the integration of Microsoft Excel or other software in the teaching of descriptive statistics?

Research methodology

The existence of technology can improve students' understanding of statistical knowledge by exposing them to tools such as Microsoft Excel. To confirm that students are being taught descriptive statistics using Microsoft Excel as an alternative way to enhance their knowledge of statistics, I conducted the research using a qualitative method. Two schools of education were sampled using a purposive sampling strategy to help identify education lecturers who could be teaching statistics using Microsoft Excel. A purposive sampling strategy is a nonprobability sampling method whereby researchers set out to find participants based on their knowledge and experience (Creswell 2009). The research reported in this paper was carried out in accordance with the guidelines and consent of the universities that agreed to participate in this study. Ethics clearance was obtained from the university that gave consent for this study. Mathematics education lecturers were provided with details of the study and were made aware that participation was voluntary before they offered their consent to participate.

The schools of education were selected because of their proximity to the researcher and ease of collecting data. The Heads of the Department in Mathematics helped in identifying the names of lecturers that are teaching statistics in their departments. Six lecturers participated in the study, three coming from each education school. They all agreed to be individually interviewed at times convenient to them. They were requested to share their experience in teaching descriptive statistics based on:

1. Use of Microsoft Excel to sort data and find measures of central tendency, that is, mean, median and the mode.
2. Use Microsoft Excel to calculate measures of dispersions, that is, range, standard deviation, quartiles and interquartile range and draw a scatter box.
3. Use the data analysis ToolPak to present data visualisation such charts (histogram, pie charts, etc.).
4. Use Microsoft Excel to present descriptive statistics summary.
5. Use Microsoft Excel to work out regression analysis, correlation, ANOVA, covariance, *F*-test, *t*-test, *Z*-score test and Fourier analysis.

Findings

The participants (using pseudonyms P1, P2, P3, etc., to hide their identity) had different opinions on the use of Microsoft Excel in teaching basic descriptive statistics. Four of the participants confirmed that they do not use Microsoft Excel at all in teaching descriptive statistics; however, they have some rudimentary knowledge of the use of Microsoft Excel for personal use. The other two mentioned that they sometimes show students how to find measures of central tendency in Microsoft Excel. Beyond that, they use traditional ways to find measures of dispersion and variability. These other concepts are beyond the scope of the curriculum. All the participants expressed willingness to be shown or trained on how to use Microsoft Excel to teach descriptive statistics. During the interview, this is what some of the participants commented:

> 'Generally, I have never used Microsoft Excel in teaching basic statistics. Most of us still teach using the traditional methods of using chalkboard and textbook.' (P3, 49-years-old, 2021)

> 'I use Microsoft Excel when solving my personal problems and I am not aware that Microsoft Excel can be used to plot scatter diagrams and calculate coefficient correlation r.' (P2, 55-years-old, 2021)

> 'I think we need some form of training on how we can use Microsoft Excel in teaching statistics. As long as we are not trained on the use of Microsoft Excel in Mathematics, we will always remain on the peripherals. It's difficult to teach using tool you are not familiar with [...].' (P4, 60-years-old, 2021)

> 'We do not have the policy that requires us to use Microsoft Excel in teaching Mathematics/statistics. However, it is an individual choice of any lecturer who intends to adopt it in their teaching [...] in some instances there are some mathematical examples solved using computing software, however personally I do not adequate knowledge in the use of computing software including the use of Microsoft Excel [...].' (P6, 51-years-old, 2021)

> 'The issue with technology is that it keeps on changing. The time you are trying to master a concept, in just few years it will be kicked out by new ones. This makes me hesitant in teaching using technology.' (P5, 47-years-old, 2021)

An arrangement was made to visit the education lecturers in these two institutions to demonstrate to them how to use Microsoft Excel in teaching descriptive statistics. The training was premised in one of the participants' offices and some demonstrations were conducted by the researcher. They were given some tasks as a form of assessments to confirm their understanding of the concepts. There are some concepts that were noted to be new to them, such as regression analysis, correlation, ANOVA, covariance, *F*-test, *t*-test, *Z*-score test and Fourier analysis.

Concerning the curriculum policy mentioning the integration of Microsoft Excel in teaching basic descriptive statistics, participants displayed limited knowledge. They mentioned that they are aware of the topics to be taught or covered. There is not much mention of instructional approaches. There is a conspicuous absence of how theory and practice of technology within the field of education can be reconciled, thus resulting in poor explanations of how technology can be used in learning (Oliver 2013). The use of Microsoft Excel in teaching descriptive statistics seems to be the innovativeness of the individual. Those who are moving towards that approach or direction indeed receive an appraisal from the department. There is little, if anything at all, about the PD of lecturers to bring them up to speed on how to integrate the ever-evolving technological skills in the classrooms.

Discussion

In general, the engagement revealed that the participants have a low level of knowledge of the use of Microsoft Excel in teaching basic descriptive statistics. They quickly mentioned that it is difficult to teach a concept using an approach one is not conversant with. They mentioned that they need to be well-prepared and thoroughly supported in that space so as to make changes in the curriculum and instructional strategies (Hartsell et al. 2009). The participants further mentioned that it is easy to teach a subject when one knows its subject matter very well, and it provides the confidence to use various approaches during teaching in an effort of trying to reach the understanding of the learners. It could be said that CK is the source for trying different instructional strategies. The use of various methods is a prerequisite in teaching mathematical statistics, which in turn motivates students to learn Mathematics or statistics concepts at ease. Unfortunately, the participants proclaimed that they were not proficient enough in teaching basic statistics using Microsoft Excel, let alone other statistical tools. Thus, they called for CPD to upgrade their existing skills that may assist in effecting change in their current instructional lesson deliveries. Professional development is a fundamental key in aligning learning needs to the current environmental needs of the students that use technology in solving problems. In addition, the use of Microsoft Excel may lead to innovation in the subject, bringing collaboration among students and lecturers. Incorporating the use of Microsoft Excel in teaching statistics may speed up redefining classroom environments that create critical and innovative learning experiences for students' higher-order thinking. In a sense, teachers at the innovator level are willing to take risks and try different instructional approaches to achieve desired learning outcomes (Christensen & Knezek 2002).

The following sub-sections outline the research questions.

To what extent do statistics education lecturers utilise Microsoft Excel in teaching basic descriptive statistics?

The research reveals that lecturers rarely integrate Microsoft excel and those that are using it do so informally. The main reason is the lack of high-level skill and knowledge of Microsoft Excel. They found it hard to run the software to perform some computations, which implies that there is limited mastery of the use of Microsoft Excel. Briefly, without adequate skill and knowledge in the use of Microsoft Excel, there is nowhere mathematics education lecturers could use the software in their instructional teaching. Therefore, mathematics education lecturers must be provided with some professional support from reputable, competent and reliable service providers that will enable them to be scaffolded to overcome their challenges in teaching descriptive statistics using Microsoft Excel.

Despite the awareness of these lecturers around the capabilities of Microsoft Excel in organising and processing data to make meaningful information in a short space of time, they are being inhibited by the knowledge of how to use Microsoft Excel functions to achieve such scenarios. Thus, this paper advocates for the use of Microsoft Excel by mathematics educators in the teaching of descriptive statistics; it is user-friendly, fun and easy to learn. Continuous teaching of mathematical symbols by mathematics education lecturers poses some challenges to students in connecting the relationship of one concept to another in descriptive statistics and presenting an analysis of the results.

How does the curriculum enforce the integration of Microsoft Excel or other software in the teaching of descriptive statistics?

There is no curriculum document in place that emphasises the use of Microsoft Excel in teaching basic descriptive statistics. Neither does the document restrict the use of Microsoft Excel; however, those who are using technology in teaching basic statistics are appraisable. It appears Microsoft Excel is used in offices for administration purposes and it has not found its way out to the classroom environment. Mathematics education lecturers still view Microsoft Excel as an administration tool which enables them to manage their work, such as capturing students' marks. Despite that, some textbooks have some mathematical examples worked out using some computer software, mathematics educators do not harness such thoughts as they have limited knowledge in that space. The threat that digital technology poses to mathematics education lecturers is its rapid change. Some versions of software come to the market and do not stay longer, making a challenge to mathematics education lecturers who have not yet mastered the use of technology in teaching. To eradicate this challenge and fiasco, CPD is the solution.

Conclusion

The study illuminated the challenges that mathematics education lecturers face in the use of Microsoft Excel in teaching descriptive statistics. There should be CPD (reskilling) on the use of Microsoft Excel for teaching basic descriptive statistics. Curriculum planners should play a leading role in PD rather than just rolling out a curriculum that will be difficult to be implemented because practitioners will lack the skills.

The study concludes that education lecturers are still grounded in traditional methods of teaching, although they could see the light at the end of the tunnel about the potentialities of Microsoft Excel in the teaching of basic descriptive statistics. There is a need to adapt a teaching approach that both uses the traditional approach and statistical software to enable students with a balanced understanding of the statistical concepts. I drew a great deal of rich information that impedes education lecturers from using Microsoft Excel in teaching descriptive statistics that relates to lack of knowledge and skill. In addition, although education agrees on the philosophy of technology in education, there is no clear policy on how technology can be used in teaching and learning. There should be a mathematics teaching policy that guides lecturers or teachers on the use of Microsoft Excel to teach basic descriptive statistics.

Contemporary education solicits education that grounds learners with cognitive thinking and complex solving skills; thus, CP is relevant when teaching using the emerging digital technologies. There is a correlation between technology, humans and the world (An & Oliver 2020). Critical pedagogy was used as a lens to encourage education mathematics lecturers to use Microsoft Excel in their teaching. Infusion of Microsoft Excel in the teaching of statistics implies that technology or software can shape education and free students from the concept of a one-size-fits-all model, where lecturers are considered as the 'knowers' and students are 'passive recipients' of the knowledge shared. Mathematics curriculum planners should scan through the affordances Microsoft Excel may have in assisting preservice teachers in enhancing their statistics knowledge base. Integrating technology such as Microsoft Excel in the teaching of basic descriptive statistics can give a thought to both the students and the lecturers about what technology 'does' to education, and what the new opening possibilities are. Exposing the students to critical consciousness, empowers them to think independently which further helps them to analyse, evaluate, address and manipulate the situations in their societies. Continuous professional development is the key to foster education lecturers to harness technology that is before them. Ultimately, it will clear the doubt and confusion about how technology can be used in education.

Chapter 12

The effectiveness of selective visible thinking tools in developing online critical thinking in first-year Chemistry preservice teachers

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Abstract

Critical thinking (CT) has been recognised as one of the most important life skills students of today can possess. It is also an important indication of student learning quality. In order to develop critical thinkers, investigation into teaching approaches and the evaluation of the development of CT is needed. Implementing visible thinking tools in the classroom might be one way of reaching this goal. Activities during the course were designed using visible thinking tools to help students develop CT and therefore improve their cognitive level of the subject. In an effort to investigate the effectiveness of visible thinking tools toward developing critical thinkers online a one-group,

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pre- and a post-test research design were conducted. The online pre- and post-tests were designed based on the taxonomies of Bloom and Webb. Statistical parameters indicate a significant increase in the higher-order cognitive levels of students. The findings reported herein demonstrate that visible thinking tools can be implemented online to successfully improve the cognitive level of students' understanding of the concept taught and therefore also their CT skills in the context of the concept.

Introduction

Developing CT in students has become a major focus for educators. Research and practice on this topic have increased significantly in the last ten years (Alsaleh 2020). South Africa is one of the most unique countries to teach in given its diversity. This study reports on an intervention implemented online to develop and improve CT in first-year students at a university in Johannesburg.

Critical thinking

Critical thinking is a higher-order thinking (cognitive) skill which goes beyond memorisation and recall of facts (Fischer 2011). According to Paul and Elder (2007), our quality of life depends on our quality of thinking; consequently, development of CT provides not only quality graduates but also quality citizens. Incorporating CT into a course would require constructive alignment. Biggs and Tang (2011) define constructive alignment as aligning teaching and assessment tasks in such a way that it teaches or assess what the learning objectives specify. Therefore, incorporating CT in a course would mean constructive alignment between *higher-order* learning objectives, the activities and content, as well as assessment.

Cognitive complexity

According to Boom's (1956) taxonomy there are six levels of cognition of a concept. It runs from low order cognition like recall or recognition through to the highest-order of cognition. Bloom's taxonomy was revised in 2001: the two highest levels (synthesis and evaluation) were switched around and the initial nouns were changed to verbs (Anderson & Krathwohl 2001). The highest-order verb now being to create. More recently, Webb's depth of knowledge (DOK) was created by Norman Webb ([2006] 1997). Webb's DOK indicates the complexity of knowledge that the assessment criteria require. It has four levels and runs from low-order knowledge like recall, to higher-order knowledge like extended thinking (Webb 2005). These levels correlate with Bloom's taxonomy but shifts the focus from the result to the cognitive and thinking process.

Teaching critical thinking

Critical thinking skills can be specifically taught in standalone courses, or it can be taught as an integrated approach to teaching (Alsaleh 2020). The choice between the two approaches is debated by researchers (Alsaleh 2020).

Studies in support of teaching CT skills as a standalone course include that of Alwehaibi (2012), at a University in Saudi Arabia, who concluded that a group of students who received explicit instruction in CT skills demonstrated a greater improvement in their argumentation skills compared to the group who did not receive explicit instructions in CT skills. This result was consistent with the findings of Kuek (2010) in Sudan who implemented an intervention of explicitly teaching CT skills to one group and not to the other. Important to note is that even though the results of these studies proved success to some extent, there might be students who chose not to take the specific CT skills course and finish school without those skills. The effectiveness of these specific CT skills course relies heavily on the teacher presenting it (Alsaleh 2020).

Hatcher (2006) argues that the integration of CT skills in any course would result in more success. The significance lies in that it would take input from various teachers to teach CT skills in different contexts. This will also provide an opportunity for the students to practise CT skills and not only learn about the theory and concepts that it consists off (Gelder 2005). It should be part of the learning objectives for each course (Kuhn 1999). Hager et al. (2003) tasked first-year students at a university in Australia to complete different tasks with the aim of developing CT skills. They had to work in groups and discuss different definitions, questions and debate on the credibility of different resources. Evidence in the form of discussion forums and questionnaires supported the improvement of their thinking and especially CT skills. In following this approach, one is assured that students will leave school or graduate with at least some amount of CT skills; this however requires trained teachers and the space to effectively deliver the teaching of CT skills (Alsaleh 2020).

Assessing critical thinking

Assessing CT skills has two components: the *assessment strategy* and the *strategy to assess* (Alsaleh 2020). The assessment strategy refers to the type of activity you are going to give the students and the strategy or approach you take to assess refers to whether you are going to have a rubric, point scale or mark allocation in a test.

The success of assessing CT skills is highly dependent on the participation of the students and therefore the educator should understand the students’ preferences and perceptions (Karns 2005), they should have a well-designed strategy (Edman 2002) and should be aware of the students' contexts and backgrounds (Alsaleh 2020). If students are instructed to use higher-order thinking to write an essay or to participate in a classroom discussion, it does not necessarily indicate the development of CT skills (Alsaleh 2020).

Different *assessment strategies* include Socratic questioning (Yang, Newby & Bill 2005), reflecting and analysing ideas and problem-based strategies (Pithers & Soden 2000). One particular technique which focuses more on the context in which students are supposed to learn is Webb's ([1997] 2006) DOK. It specifies activities which can be implemented in different scenarios, settings or situations (Serin 2019).

Varied research on *strategies to assess* CT skills have been published (Al-Fadhli & Khalfan 2009; Codon & Kelly-Riley 2004; Facione & Facione 1994) and the use of a rubric or point scale is mostly evident.

Visible thinking tools

Visible thinking is a research-based approach which provides an open method for developing student thinking across different discipline contexts (Project Zero n.d.) and can be implemented online. It serves the purpose of developing student thinking and deep learning. Researchers who started the Visible Thinking initiative were Dave Perkins, Shari Tishman and Ron Ritchhart (Project Zero n.d.). This initiative has grown into what is now called 'thinking routines' which are easy mini-strategies that extend and deepen students' thinking. These routines are not only a practical way of implementing CT in courses but can also be implemented online.

Context of the study

South Africa faces serious challenges in its schooling system and performs poorly in international studies (Ngozo & Mtantato 2018). Overcrowded classrooms, corruption and violence, undertrained teachers and students are some of the important issues described by Mouton et al. (2012). Taking this into consideration, it is no surprise that there is very little to no opportunity or time for the development of CT skills which South Africa needs so much. In a City Press article by Mokoena (2019), it is noted that CT might be the one thing that can save South Africa. South Africans need to have the life skills and CT abilities to be able to promote social development and economic growth (Grosser 2006):

> Therefore, it is essential not only to convince educators that the teaching of thinking skills is important, but they also need to be equipped to become effective thinkers themselves. They should be knowledgeable on how to teach thinking skills before they can teach learners how to become effective thinkers. (p. 363)

Paul and Elder (2019) argue that there are two important levels of thinking that students must master in order to improve thinking to another level. They first have to be taught the elements of thinking. This includes reasoning through problem-solving, making assumptions, different point of view and creating evidence. The second dimension they need to master is the ability to assess the quality of reasoning. This includes quality standards like accuracy, precision, significance, depth and width. The development and movement through these levels repeatedly and continuously improving on reasoning, and the quality thereof will lead to the development of a well-cultivated critical thinker. A well-cultivated critical thinker can formulate important questions clearly, can interpret collected information effectively, can evaluate solutions, is open-minded and communicate effectively during problem-solving processes.

The purpose of this study is to investigate the effectiveness of using visible thinking tools as a method to develop higher-order thinking (CT) in preservice teachers. Pre- and post-tests will be used to capture the possible change in cognitive level.

Research design

Methodology

The conducting mode of this study was completely online, as it was during the COVID-19 pandemic.

The study focused on the first-year BEd (Senior Phase or Further Educational Training) Chemistry course conducted at the WSoE at the University of Witwatersrand. This was a 5-week online course on the topic of Matter and Materials. This project investigated the effectiveness of using selective visible thinking tools to develop CT.

The one-group, Quasi-Experimental time series research design was chosen as no comparison or control group is needed (Engel & Schutt 2014). Observations of the group are made before and after the completion of the course.

Students were asked to complete a pretest at the beginning of the course. The pretest served the purpose of determining the cognitive level with which students entered the course. During the course, students were given constructive tasks and activities to complete. These activities were specifically designed to develop CT skills in the students. At the end of the five-week course, students were asked to complete a post-test capturing the cognitive level with which students left the course. Cognitive levels before and after the course intervention could be compared to determine if a significant change was evident.

Participants

The pre- and post-test was developed and made available online to 200 first-year students at the start and at the end of the course. The tests were set using two separate Google Forms and the links then made available to students via the online learning system of the course, Sakai, before and after the course. Completing the test was voluntary and students only had one chance to complete the test. Responses from 114 students were received on the pretest and 39 responses on the post-test.

Pre- and post-test

Each test consisted of 25 questions in total and was conducted online. Questions were constructed using verbs based on the different cognitive levels of Bloom's taxonomy. Before analysis, the questions were grouped to correlate to the four cognitive levels of Webb (as shown in Table 12.1). There were five to eight questions per cognitive level in each test. The questions were a combination of multiple-choice type questions and a few short answer questions which the students needed to answer by typing in a textbox.

An example of a question that would fall into the recall and reproduction category (green) was: gas X and gas Y can be collected using the apparatus shown in Figure 12.1. What can you infer about X?

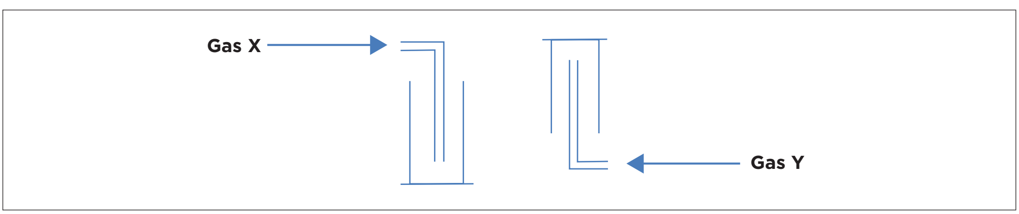
Simply put:

- *X is less dense than air.*
- *X is slightly soluble in water.*
- *X is denser than Y.*
- *X is less soluble in water than Y.*

TABLE 12.1: Solubility of different compounds in different conditions.

Compound	Heat	Cold water	Hot water
Calcium fluoride	No effect	Insoluble	Insoluble
Naphthalene	Sublimes	Insoluble	Insoluble
Potassium chloride	No effect	Fairly soluble	Very soluble

Note: These are typical observations (facts) in the lab when determining properties of chemical compounds presented in table format. For example, salt is soluble in cold water and in warm water; and shows no effect to dry heating. Sand is also showing no effect to dry heating but is insoluble in cold and warm water.



Source: Author's own work.

FIGURE 12.1: Collection of different gasses.

Students had to recall what they had learned regarding the densities of gasses and show an understanding of the collection techniques for gasses to be able to answer this question.

Another lower-order thinking example that would fall into the skills and concepts category (blue) was: *A mixture contains naphthalene, calcium fluoride and potassium chloride.* Table 12.1 gives some of their properties.

- ***Describe how you would obtain dry and pure samples of all three compounds from the mixture.*** Students had to use the properties given for each compound and apply it to plan a purification method based on the purification techniques they were familiar with. A higher-order thinking question (purple) would include questions like the next example.
- ***Some scientists predicted that there are rivers of methane on a moon called Titan. Methane has a melting point of −182 °C and a boiling point of −161 °C. What do you think the temperature on the surface of Titan is that led to the scientists' prediction?*** Students had to analyse the information given and reason through the knowledge they have on the topic to be able to make a probable prediction of the temperature on Titan. The last category (orange) asks that students uses their highest-order thinking levels. An example of one of these questions included is the next example.
- ***As a scientist, you are asked to design a new element for the periodic table. The element must be stable. Add and describe some of your design elements and the properties it will give the element. Also, predict where on the periodic table the element might fit into.*** Students need to relate the structure and composition of elements to the physical properties it poses because of those elements. They then must decide on feasible properties for a stable element and plan the design elements they would use to be able to reach the goal.

Standard mark allocations were used to assign marks to the questions. The questions were marked and marks allocated accordingly. The combined mark allocation of grouped questions was assigned as the mark allocation for the first category, etc. Analysis was performed per category. A normalised gain calculation was carried out to determine the overall effectiveness of the study. To determine the significance in the difference of the mean scores within each category, a *t*-test was used.

☐ Course activities

One particular technique which focuses more on the context in which students are to learn is Webb's DOK (Serin 2019). It specifies activities which can be implemented in different scenarios, settings, or situations. Of the four levels it consists of, it is level 3 and 4 that promotes strategic and extended thinking activities (Webb [1997] 2006).

The course activities were designed to develop CT skills in students. Therefore, course activities are focused on improving strategic thinking and reasoning (purple) and extended thinking category (orange) using visible thinking tools or routines.

These tools are mini-strategies, and the higher-order learning outcomes become the basis on which tasks for CT development are designed.

The strategies selected include:

- evidence-based reasoning
- clarifying truth claims and reason with evidence
- what you think you know about this topic; what questions you have; how you can explore this topic
- connect new and old knowledge
- creative decision-making
- reflecting on how and why thinking has changed.

These strategies fall within the last two categories of Webb's learning framework (see Table 12.2).

The example of an evidence-based reasoning task is called 'What makes you say that?'. In this task, students had to make a video of how they made their own homogeneous and heterogeneous mixtures. They had to defend their choices, give some theory on the differences between mixtures and apply that in their choices.

One of the last tasks in the course was called 'I used to think [...], but now I think [...]'. Students not only had to reflect on whether their thinking on the topic has changed but also how and why it changed.

The marks obtained by the students for the specific tasks are not captured in this study, as the tasks were used as a tool to improve critical and higher-order thinking, not to measure it.

TABLE 12.2: Correlation between Bloom and Webb learning frameworks.

Learning framework	Bloom	Webb
Action	Pretest and post-test	Constructing tasks using visible thinking tools to make visible development of cognitive level and thinking process
Cognitive level	Remember	Recall and reproduction
	Understand Apply	Skills and concepts
	Analyse	Strategic thinking and reasoning
	Evaluate Create	Extended thinking

Source: Adapted from Miller (2018).

Results

This study was designed to assess the effectiveness of developing CT by the implementation of visible thinking routines in a first-year group of students. Firstly, the normalised gain between the means of the pre- and post-test within each category was calculated (Hake 1998). Hake claimed that a value > 0.7 can be regarded as a high <g> (rarely found), medium <g> value is considered between 0.7 – 0.3 and a value below 0.3 is a low <g>.

TABLE 12.3: Normalised gain between the means within each category.

Category	μ (pretest) %	μ (post-test) %	Normalised gain value $\langle g \rangle = \frac{\mu Post - \mu Pre}{100 - \mu Pre}$	Extent of gain
Recall and reproduction	56.69	69.60	0.3	Medium
Skills and concepts	58.95	58.97	0.0	Low
Strategic thinking and reasoning	34.87	51.28	0.3	Medium
Extended thinking	21.05	41.03	0.3	Medium

Both the higher-order thinking categories (purple and orange) showed a medium <g>. This result gives an initial indication that the intervention did improve the higher-order thinking and therefore CT in this group of students slightly.

Significance of the change in cognitive level

From the results of determining the normalised gain, an indication of gain can be seen in the higher-order thinking categories. It is therefore important to determine if this gain is significant by doing a *t*-test.

The mean score of each category in the pretest was used as μ (the population mean, variance unknown) and the mean score of each category in the post-test was used as $\underline{x}$ (sample mean, standard deviation known). To calculate the *t*-statistic the following formula was used:

$$t = \frac{\underline{x} - \mu}{s / \sqrt{n}} \qquad \text{[Eqn 12.1]}$$

TABLE 12.4: The *t*-statistic for the scores in each category.

Parameter	Recall and reproduction	Skills and concepts	Strategic thinking and reasoning	Extended thinking
M	56.69	58.95	34.87	21.05
n	39	39	39	39
$\underline{x}$	69.60	58.97	54.27	41.67
S	19.44	24.99	24.70	24.56
***t*-statistic**	4.155	0.007	4.907	6.242
Significance	Yes	No	Yes	Yes

The t-critical value at a 99% confidence level (α = 0.01) was 2.423. A one-tailed test was used, as improvement of the scores was expected. The significance of the difference between the pre- and post-test scores is indicated in Table 12.4. Thus, it can be said, with 99% confidence, that there was significant improvement in the scores of Webb's DOK levels in 1, 3 and 4.

Discussion

In this study, first-year students entering a Chemistry course as preservice teachers were given a pretest to determine their cognitive level on the topic of Matter and Materials. During the course, students were subjected to various tasks online designed by using visible thinking tools which were grounded in Webb's DOK which focuses on the thinking process. To capture the cognitive level with which the students left the course, a post-test was conducted.

Focused tasks given were expected to improve the strategic thinking and reasoning and extended thinking categories, not the lower-order thinking skills. However, the lowest-order cognitive skill (recall and reproduction) was also improved, and this could be contributed to the general increase of knowledge gain by students through a course. The skills and concepts category did not show any gain. This was to be expected as tasks given were focused only on the 3rd- and 4th-level category, and the course was presented online without time spend hands-on in the laboratory.

Overall, the results showed that implementing visible thinking tasks in a first-year course significantly improves the students' CT skills. Implementation of different ways of teaching and developing CT skills can likely contribute to the development of students' CT skills.

Conclusion

When teaching and assessing CT skills, various aspects regarding students, strategies and methods of implementation need to be considered.

The *strategy to assess* was to give a standard mark-allocated test which captured the cognitive levels of students. The *assessment strategy* which was used to develop higher-order thinking skills was to give students tasks designed from visible thinking tools grounded in Webb's DOK. The method of implementation was to teach and assess critical skills within (as part of) the course. The results of this study show consistency to similar studies discussed earlier. A significant improvement in students' higher cognitive levels could be observed.

Ongoing research will be to focus on improving CT over a longer period instead of only five weeks with more repetition cycles. It would also be important to include other disciplines and year levels.

Chapter 13

Effective online pedagogical practices in an ICT literacy course for first-year preservice teachers lacking computer skills

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Abstract

The purpose of this study was to investigate how first-year preservice teachers with no computer background acquired ICT literacy skills through online instruction. It is a mixed methods research that uses an explanatory sequential design. The community of inquiry (CoI) is used as a lens to identify the pedagogic practices developed in the ICT literacy course under study. A total of 111 students responded to a questionnaire distributed on their tutor WhatsApp groups, and the findings were used to create questions for the two focus group interviews that had 11 participants who volunteered to be interviewed. The use of multimedia, instructions, guidelines, chunking of content with short informative and formative assessment emerged as online

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pedagogical practices that enabled first-year students to successfully learn new computer skills online. Furthermore, the students benefited from the communication structure that provided them with the support they needed and thus, promoted self-regulated learning.

Introduction

The current generation of first-year preservice teachers can be broadly referred to as digital natives (Prensky 2001) because they grew up with technology around them (Baltaci-Goktalay & Ozdilek 2010; Teo, Yurdakul & Ursavaş 2016) and use it daily. This may imply that they have digital literacies that they need to navigate their way around online learning environments because the graphical user interfaces tend to be similar. They are therefore not afraid to click to find the right tool or page with the content they need. However, some literature has proven that this is a fallacy (Jones et al. 2010; Kimmons, Clark & Lim 2017). The frequent use of devices does not translate to using the technologies for educational purposes (Corbeil & Valdés-Corbeil 2007). Dinçer (2018) advocates for the interaction of technology, content and pedagogy, a view that Mishra and Koehler (2009) argue for in their technological pedagogical knowledge (TPACK). The challenge is that in their model, the knowledge needed by teachers to integrate different tools for teaching specific subjects is not specified (Kim et al. 2013). Strategies for preparing these future teachers should be researched to avoid inappropriate use of technology and thus compromise the quality of education (Webb & Cox 2004).

First-year preservice teachers 'are just beginning their academic training, and therefore they lack both the professional experience and a solid theoretical foundation about their teaching role' (Sánchez-Prieto et al. 2019:161), making it difficult to contextualise an ICT literacy programme that should prepare them for teaching. Most of these students have not used the technologies as educational resources (Maher 2018) and they therefore are in the Knowledge Acquisition Phase (UNESCO 2018a). While they might not have 'actual professional experience when they begin their training, they do have an idea of what teaching is and what they consider good practices' (Sánchez-Prieto et al. 2019:161). There is therefore no reason why their digital literacy programme would not be contextualised in their prospective teaching subject that they have chosen because they are familiar with it.

Significance

Teacher-training institutions play a key role in preparing teachers (Kay 2006). However, there is paucity in the design, content and delivery strategies of these ICT training programmes (Heitink et al. 2016). Most studies conducted on preservice teachers' readiness to use ICTs for teaching, focus on students who are about to graduate (Baydas & Yilmaz 2018; Parkman, Litz & Gromik 2018). Attention is not given to whether their learning experience in their first-year orients them adequately so that they can sharpen their knowledge and skills in the course of their training.

Background

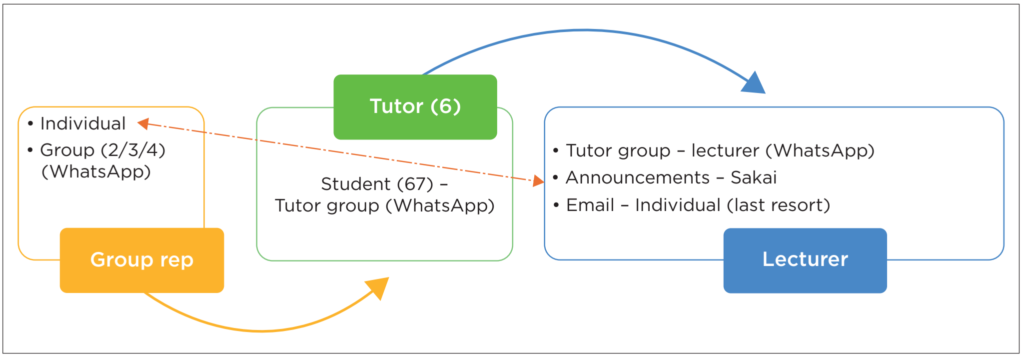
The ICT literacy course under study was offered to first-year students in a South African Initial Teacher Education institution (ITE). In its first year (2020) it had been designed for blended learning and when COVID-19 hit, after a month of its implementation, it had to be offered fully online. The course had six tutors who were registered for honours and master's in education who supported students with technical and instructional issues online. Assessment tasks designed to be for group work caused students a great deal of stress as they experienced challenges related to group dynamics. Flexibility with deadlines became the order of the day as students struggled to identify content and at times, access the course because of connectivity and competency issues. The course lecturer and tutors were inundated with a great deal of activity 24/7 on e-mails with the lecturer, on WhatsApp with group members and tutors. In 2021, a year after, the course was more organised and structured, and this was carried out by giving extra attention to refining the course design and development, management, communication and support structure.

Course design and development

Careful attention was given to scaffolding each topic, bearing in mind that the students would not have contact sessions as connectivity and device challenges were expected. The first assumption was that some of the students might not have had contact with a computer. The second assumption was that what the students knew about teaching was their school experience and therefore as tools were introduced, a short brief on its relevance to teaching and its affordance were given. Content in modules was chunked to minimise scrolling and active buttons clicked to move from one page to the other to reduce cognitive load. Links to short quizzes, discussions and assignments for submissions were accessed on the module pages.

Course management and communication and support structure

Students received new content on the LMS for the week every Monday by 12:30 pm, and this helped them organise themselves. This was their first course



Source: Author's own work.
FIGURE 13.1: Communication structure.

period on the timetable. Task submissions were at the end of the week. Their second period on Fridays was reserved for 'Clarity' sessions, where they could meet with the lecturer virtually. For questions related to instructions and content online, students were referred back to the course site. If there were unclear instructions, the lecturer shared the screen as she explained how to or where to find content. These sessions were recorded and shared the following Monday for students who could not attend. On average, 25 out of 394 students attended these sessions and the rest could access the recording on the course site. The communication structure served to establish the support structure that is illustrated in Figure 13.1.

The first point of call for the individual student was their group. This group comprised of three to four students who chose one of them as the Group Representative (Rep). The responsibility of the Rep was to coordinate group activities and to escalate unresolvable issues to the tutor. The tutor managed ± 70 students who were divided into these small groups. The management entailed providing explanations to content and instructions. Tutors escalated serious challenges to the lecturer on WhatsApp or during tutor group meetings that happened once a week on Microsoft Teams. Thus, the lecturer was the last point of call for the student.

At the beginning of the year, e-mails were overwhelming, but in the second quarter of the year they reduced significantly, and by the third quarter, no student contacted the lecturer on the course content as they had adjusted to the communication strategy. When the lecturer took over one of the tutor groups because of the tutor withdrawing, students asked a few questions in the tutor group. This was the opposite of what the lecturer had experienced the previous year (2020), and the researcher who is the lecturer for this course, sought to find out what online practices enabled 343 out of 394 students to pass the first semester of this practical computer course online without synchronous instruction. More attention was focused on the students who were in contact with a computer for the first time in 2021 and yet they passed the course with 70% and above.

Research problem

In 2021, first-year preservice teachers in South Africa joined universities with little or no knowledge of online teaching and learning (Mafunda & Swart 2020). What worsened their case is that they had never owned or worked on a laptop or desktop computer. Although the universities either provided them with laptops or allowed them to stay on campus to access computer laboratories, they did not know where to start. These students are victims of the digital divide (Dube 2020). It is a challenge to equip these first-year students with no technical skills without having physical contact with them for demonstrations. It is therefore in the interest of this chapter to investigate what online pedagogical practices assisted students with no basic computer skills in acquiring them.

The research question is: *What online pedagogical practices prepare students lacking computer skills for ICT literacy?*

The subquestions are:

1. How did students experience the course content, instructions, communication and support structure?
2. What online pedagogical practices were of benefit to students who were operating computers for the first time?

Literature review

Digital literacy preservice training

Digital literacy is considered as ICT literacy in this study. It is generally understood as basic computer skills that anyone using a computer, regardless of their occupation should have. 'Technology literacy and technology use are different concepts' (Dinçer 2018:2701). Jones-Kavalier and Flannigan (2006:9) describes digital literacy as that which represents 'a person's ability to perform tasks effectively in a digital environment'. It therefore needs to be defined in a specific context – where it will be used, and standards are determined (UNESCO 2018). Therefore, ICT training programmes should give preservice teachers opportunities to experiment with digital technologies in preparation for their use in the classroom (Albirini 2006). Steketee (2005) has come up with a classification of preparatory approaches that can be incorporated in the training of preservice teachers which are: the ICT skills development approach, the ICT pedagogy approach, the subject-specific approach and the practice-driven approach. A training programme that captures all these four approaches, can orient a student into the teaching practice, so they are able to develop critical skills they need to engage the technologies to enhance the teaching of their subjects.

Online learning practices

Online learning is analogous to distance education, and it incorporates a wide range of technologies and learning processes such as computer-based learning, web-learning, virtual classrooms and digital collaborations (Urdan & Weggen 2000). This learning environment may include electronic media, audio or video recordings, and many other interactive tools that may be available online. These tools come in different genres that enable a variety of delivery methods and formats such as multimedia, games and simulations. These environments are characterised by a wide range of pedagogical practices with active learning and student-centred techniques (Baker 2016). Flexibility, anytime and anywhere is a feature that makes online learning different from f2f learning, given the diverse circumstances of university students.

This type of learning environment 'requires moving beyond traditional pedagogy to adopt new practices' (Keengwe & Kidd 2010:537). There is more responsibility for the instructor that entails establishing structures and processes (Sugar, Martindale & Crawley 2007) that can make both the teaching and learning experiences less stressful and thus promote the achievement of learning outcomes. It is the pedagogy and not the technology that drives and determines the success of online learning programmes (Shieh, Gummer & Niess 2008).

The responsibilities that an instructor has online relates to, planning and course design, instructive and social roles (Alvarez, Guasch & Espasa 2009). There are four additional roles: ongoing and meaningful communication and interaction; instruction and learning; management and administration; and use of technology (Keengwe & Kidd 2010). In the same vein, Jones, Kolloff and Kolloff (2008); Wegmann and McCauley (2008) emphasise the establishment of a strong learning community among the students that serves well in creating social presence in the physical absence of the instructor. Fisher and Baird (2005:91) argue that 'When an online course is built with community in mind, it can then be sustained throughout the duration of the course'.

Berge (1995) and Keengwe and Kidd (2010) highlight the following online pedagogical practices: pedagogical, social, managerial and technical. These can be described thus:

> Pedagogical role revolves around educational facilitation while the social role is creating a friendly social environment necessary for online learning. The managerial role includes agenda setting, pacing, objective setting, rulemaking, and decision-making while the technical role depends on the instructors first becoming comfortable with the technology being used and then being able to transfer that level of comfort to their learners. (p. 536)

Coppola, Hiltz and Rotter (2002) include the affective (student-student; student-faculty or instructor; student-learning environment) role that the instructor should establish and sustain throughout the course duration. They therefore play the role of a facilitator, teacher, organiser, assessor, mentor, counsellor, problem solver and liaison (Keengwe & Kidd 2010:536). If these were to be implemented in any given online learning experience, the instructor would not manage, and this is the reason why this teaching space demands that time be given to plan and come up with strategies that can work for the audience and the context they will offer the programme to.

Barriers to online learning

Access to hardware, software and Internet connection is the first step to having an online learning experience. In addition, technical skills for both learners and instructors determine the extent to which they can efficiently and effectively make their experiences productive. All these factors have been cited as barriers to online teaching and learning (Nkonge & Gueldenzoph 2006). Without adequate training, support, designing of interactive learning environments that employ technologies (Allen & Seaman 2008; Keengwe & Kidd 2010; Keengwe, Kidd & Kyei-Blankson 2009) with desired affordances, the learning experience is bound to be what Fisher and Baird (2005) refer to as 'digital pot-holes' that lead to student failure or dropout from their studies. The knowledge of students about their technical competencies, types of digital devices they have access to, knowledge and access to the Internet play an important role in accommodating them in the design of materials and instructions online (Jones et al. 2008). This would therefore reduce student anxiety and make them feel that they have the capacity to tackle the learning activities.

Online learning materials

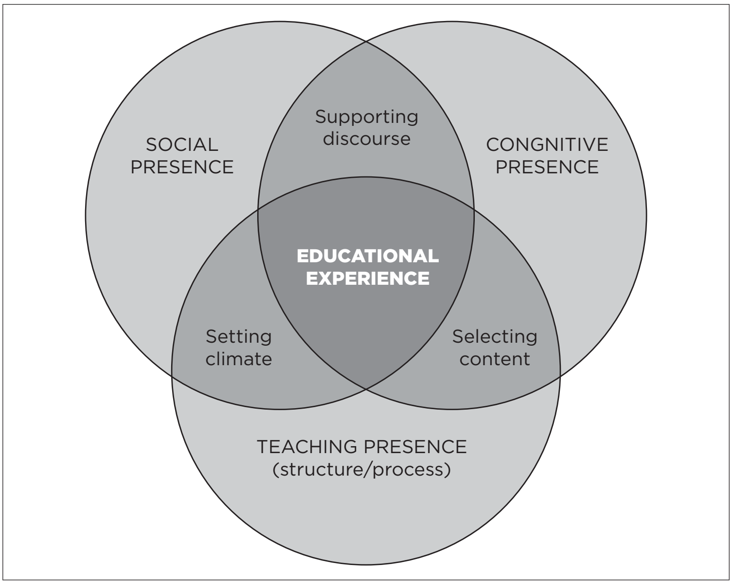
In the absence of the instructor to explain learning materials, care should be taken to ensure students can understand and follow instructions on the site. The meaningful use of multimedia becomes inevitable in this case. Mayer (2002) posits that when multimedia is used, students understand an explanation better when it is presented in words and pictures than in words only. Multimedia use on a computer can entail narration and animation. Students can 'construct verbal and pictorial mental models to build connections between them' and yet when words alone are presented, cognitive functions may be strained and thus reduce the chance of making concrete the content (Mayer 2002:27).

The ease that engagement with materials fosters on students has potential to support student motivation and self-regulation in online learning (Fisher & Baird 2015). The establishment and management of dynamics in groups, enforce team playing that helps to take on some of the instructor's affective, cognitive and support roles (Coppola et al. 2002). This can be accomplished by incorporating collaborative learning tasks where students can then engage in discussions on the concept at hand. Student participation also depends on whether the course structure inculcates the dual identity of the student as an individual and a member of a learning community or not (Fisher & Baird 2005). This helps the student to consider what steps to take and who to consult in the community to succeed.

Theoretical framework

The practices covered in the literature review encapsulate Garrison, Anderson and Archer's (2000) CoI model (Figure 13.2). The model focuses on the learning process that takes place as the student and the instructor participate in this knowledge-building experience. What constitutes this learning experience are the cognitive presence, social presence and teaching experience.

This model locates the other practices in the context of the three constructs. For instance, the cognitive presence would include selection of content, which is an instruction role that is informed by the learning outcomes to be achieved and the context that learning is happening from. This could be associated with Shulman's (1987) PCK. In the case of the ICT literacy course taught to these first-year preservice teachers, the content and the design was informed by



Source: Garrison et al. (2010:6).
FIGURE 13.2: Community of inquiry model.

the UNESCO ICT-CFT. In addition, the teaching presence (the teaching process) should include how the materials are developed to ensure students with barriers (lack of computer knowledge, skills and attitudes) adapt to this new learning environment.

Learning does not only involve instruction and cognitive engagement, but the atmosphere or climate created by the instructor determines whether students will receive all the support they need as they engage with learning material in this learning community. This is social presence – the sense that there are people in the learning space that the student can 'talk to', consult and rely on (supporting discourse) as they tackle unfamiliar content and, in this course, new terminology, tools and skills (how to). The communication medium that create the context of the learning process are the tools that students learn from. This study therefore adopts CoI as its lens for identifying online practices that helped students in this course with no computer knowledge to complete their first semester successfully.

Methodology

This study sought to investigate what online pedagogical practices enabled first-year students with no computer background to pass the ICT literacy course in the first semester of 2021. It is a mixed-method research that aims at understanding the learning experiences of these students that can help in the acquisition of computer skills. It uses an explanatory sequential design (Creswell & Clark 2017) that began with the collection and analysis of quantitative data to gain an overview of the students' learning experiences and learning environments online. Responses from 15 structured and two semistructured questions from the questionnaire were used to formulate questions for the interviews. Sequential quan-qual data analysis (Teddlie & Tashakkori 2009) was used to identify what online learning practices helped students.

The study took on a multistage sampling approach (Palinkas et al. 2015) to identify students who passed the course with a mark of 50% and upwards. In a class of 394 students, 342 students passed. A Google Form was sent to the class through the six tutor WhatsApp groups, requesting that students who had passed the semester participate. A total of 116 students responded, and five responses were withdrawn because the students did not indicate if they passed the course or not. This was an important requirement for participants in this research. Therefore, 111 responses were considered and that made up 28.2% of the targeted population of students in this first sampling phase.

In the second phase, this research sought to identify students who had never used a computer before and yet they passed the course with a 75% mark (distinction) and above. Thus, purposive sampling was used (Cohen, Manion & Morrison 2000) and this was the qualitative aspect of the study.

A total of 15 preservice students qualified for this phase, and 11 of these students volunteered to be interviewed on Teams and thus two (A and B) focus groups (with five and six students each) were formed. The focus groups were conducted on the same day, the 18th of November 2021. Themes emerged from the content analysis that helped identify online practices that created an appropriate learning environment for the students.

Findings

The data presented in this section is from the questionnaire (quantitative) and the focus group interviews (qualitative). Table 13.1 summarises the findings from the questionnaire that demonstrated how ICT infrastructure, ownership of technology, clear instructions and the communication strategy are significant in enabling students in this class to complete the course successfully.

Most preservice teachers who participated in this study were staying on campus where they could easily access ICT infrastructure and support from peers. While most of the students expected to acquire computer skills in this course, they found the activities in the course relevant to teaching. Confidence is critical in adopting ICTs for teaching (Hennessy, Harrison & Wamakote 2010; Jamieson-Proctor et al. 2006; Kamalodeen et al. 2017). Preservice teachers in this course felt confident to use ICTs. In summary, students' responses indicate that: (1) instructions, (2) content structure, (3) groups, (4) tutors and (5) the learning environment contributed to their success.

Interview questions focused on understanding how these five aspects of the course enabled students' successful engagement with the course. Responses from the two groups were similar in their explanations of the online practices.

Instructions

Students found instructions clear because of the way they were presented, for instance, Student 1 in Focus Group A said:

> 'So, I think the instructions were very clear because you would show a picture or something and point at it on the computer so it was easier for me to locate that something because I would. Also, it would be easier for me to search for it because I can relate to the picture that you are showing in the instruction and actually just see that, "oh, she's talking about this. This is where I'm supposed to do, and the words written under each picture or..." About each picture, as instruction of what I'm supposed to do. And yes, I think that was the most like it was. It was beneficial for me.' (Student 1, Focus Group A, female)

This student confirms Mayer's (2002) view that students understand better when verbal instructions and pictures are used at the same time. In her case, the student could relate to what was said and the image helped her concretise

TABLE 13.1: Findings from the questionnaire.

Question focus	Data
1. Performance in first semester	52.3% – Score: 75%–100% 21.6% – Score: 70%–74% 12.6% – Score: 65%–69% 7.2% – Score: 60%–64% 6.3% – Score: 50%–59%
2. Able to operate mobile phones	E-mails, videos, Google search function, create documents, edit content, chat, share documents
3. Able to operate laptop/computer	69.4% – basic operations 13.5% – for entertainment 13.5% – first contact with a computer
4. Residence during first semester	74.1% – at university residence 17.2% – townships 5.2% – suburban home 3.6% – rural or external residence
5. Laptop ownership	62.1% – own 19% – sharing with family 15.5% – university lab 3.4% – neighbour's or friend's
6. Access to Internet	81.8% – university 11.3% – home Wi-Fi 7% - home data
7. Expectations	94.6% - technical skills 5.4% – used for teaching
8. Ability to follow instructions	62.1% – clear instructions 22.4% – group members 15.5% – tutor
9. Understanding of content	40.5% – content presentation 35.3% – videos 20.7% – instructions 3.6% – all of the above
10. Success attributed to individuals	Tutor, groups, friends, lecturer
11. Communication strategy usefulness	71.6% – scored 4–5 (Likert scale) 20.7% – scored 3 7.8 % - scored 1–2
12. Relevance of course to teaching	95.7% – scored 4–5 3.5 % – scored 3 0.9% – scored 2
13. Now confident with computer use	92.2% – yes 6.1% – maybe 1.7% – no
14. Advice for 2022 intake	Read and follow instructions, seek help, collaborate with group members, do all activities
15. Rating self on competency in topics covered in the following: Understanding ICT in Education; organisation and administration; curriculum; assessment; collaborating with other teachers; how to use ICT for teaching and learning	Most rated themselves – exceptional or very good

what was explained about the features on the computer and other concepts that were new to them.

In addition, other students said they benefited from the videos created by the lecturer and those from YouTube that students referred to as 'loud and clear' as they helped them to understand what was expected of them in the tasks that were given. They also commended the open education resources that they had been referred to for instructions on how to carry out procedures for specific tasks. Student 3 indicated that as much as she had never used a laptop before, she knew how to Google on her phone and did the same on her laptop to gain more understanding about, for instance, creating teaching content that can be saved as a video (mp4 file).

The students had a wide range of representations of texts they could go through to help them figure out how to carry out course tasks. Student 5 explained:

> 'Being [*having*] instructions like written on their own, just sentences, tend to be difficult sometimes to understand their technicality and the terminology otherwise, but uploading videos and pictures, you know, at demonstrating actually worked. And was actually helpful? Because you can now see what is it exactly that you need to do, and then you get a better understanding from that.' (Student 5, Focus Group A, male)

This student also confirms Mayer's (2002) assertion about the importance of using both words and pictures in an explanation or demonstration, in this case. While Student 7 from the second focus group also added that the language used was understandable and easy to read too, Student 5 struggled with the terminology and had to rely on videos and illustrations in the demonstrations to make sense of the instructions.

Content structure

The students appreciated that the course started from basics and there was evidence that the content catered for those who knew nothing about computers. They found the slides that explained the parts of the computer helpful in understanding further instructions as the course unfolded. Student 1 in Focus Group A (female) stated:

> 'OK, ma'am, in terms of the content, I think the content was very clear because you'd include videos, real-life experience as an example. So it will be easier to relate with and the computer basics parts they was also very helpful, especially for a beginner like myself who doesn't know anything about a laptop, so it becomes very much easier if you set the contents towards that part, end towards engaging with the whole content of ICT things. I think that is very helpful.' (Student 1, Focus Group A, female)

Student 5 in Focus Group A (male) reiterated:

> 'I think the content was pretty much organised, it was like, you didn't put it in a way that you thought everyone knew about it – how to operate a computer, right? So it started from a very low level and then building.' (Student 5, Focus Group A, male)

Regarding chunking of content, the same student (Student 5) had this to say:

> 'Bits and pieces of information put together. It was well put together in a way that everyone could understand it, even someone who doesn't know anything about. Uh, computers or? Maybe who doesn't have the digital literacy skills you know. So yeah, the content was pretty much well organised. If I could say and then it was not haphazardly placed.' (Student 5, Focus Group A, male)

Student 4 in Focus Group B added:

> 'About the content, ma'am. What I liked is that it was divided into small sections, I see. So, uh, focusing on a section that is that is not full of, uh, too much information makes it easy for us to grasp that information instead of it trying to cast a lot of information at once, you see, I like that it was divided into small sections, that was really precise and understandable.' (Student 4, Focus Group B, male)

Content presented on videos helped clarify what they did not understand as well. Based on these extracts, it is clear that these students were well catered for as the basics helped them build on what they were not aware of initially.

Groups

Students found working in groups to be a challenge because of group dynamics and at times because of issues that were beyond their capacity, such as connectivity. Their challenge as expressed by Student 5 in Focus Group B were:

> 'Uhm, honestly, they did work. They did not work somehow because. And considering working with people that you don't know, you've never seen the distance, you don't know whether like it's very difficult to contact people this like now. It was very difficult to reach us out.' (Student 5, Focus Group B, female)

Despite the challenges the students experienced, they agreed that with time, they found a way to work with each other. Student 1 in Focus Group A (female) brought into light what the literature says in terms of establishing a community that takes responsibility for each other. She explained how although she was working with difficult people, the main lesson she learned from the experience was the patience to complete tasks. Student 2 in Focus Group A (female) appreciated the care she received from the group that checked on her and she relied on them whenever she was 'lost'. She added that she developed friendships and support that extended to other subjects. The literature covered in this research agrees with Student 5 in Focus Group B about online learning in the next extract:

> 'Yeah, I think I'd like to add on to what others said about, you know, the importance of interacting with your group members and getting their opinion and their thoughts on the particular content or topic that you're doing for that week or their time. It's important because sometimes you will tell yourself that no, I understand this and I've got this, only to find out that you are not exactly on the right path, so you need other people's thoughts and opinions. So if you put your minds together, you know? Yeah, it's really it's really fruitful and is effective in that way. Online, you can never be on your own. You can never tell yourself you can do this on your own.

> You need one another. You need each other to in order to say you will cruise nicely in this course.' (Student 5, Focus Group B, female)

This statement is profound as it reiterates the importance of the support that the instructor should incorporate in her delivery strategy. Student 6 in Focus Group B added:

> 'We were also able to help each other with notifications. We were able to notify each other to remind each other that "OK, guys, don't forget that we are submitting work on Friday. Don't forget that in ICT we have to do this." If somebody made a mistake somewhere somehow we would correct them. For instance, there was a time when we were writing. I don't remember what we were writing – parallels at the beginning of the year. We had to write something as a group and share it with our group members. Therefore, our group members would read what she had written. If you made a mistake, they will come to you. "Do that, OK. You made a mistake here and here. I suggest that you fix it like this," and then we fix our mistakes. So for me, that's why I gained a lot.' (Student 6, Focus Group B, female)

Tutors

Students did not have a good story to tell about their tutors. Some did not know who their tutors were, and some moved to active groups where they could receive immediate feedback after struggling to receive a response. However, other students found their tutors helpful as screenshots and videos would be shared for guidance

Learning environment

Students living in the university residences were grateful that they could come and be in an environment where the ICT infrastructure was stable and accessible. This made it easy for them to support each other in their groups and meet submission deadlines. The residences were described as 'learning friendly and spacious' by Student 5. On the other hand, they appreciated the support structure they have in their university that goes beyond academia. It includes mental health (very important during this crisis) and human touch with those having similar experiences where they could support each other.

Clarification sessions

Students in Focus Group A felt no need to attend these sessions as the instructions were clear. The approach that had been used by the lecturer encouraged Students 1 and 5 in Focus Group A to (female and male, respectively) learn to read for themselves as they were often referred to the course site for content that they needed by their tutor and the lecturer. In the case with Focus Group B, Student 6 (female) did not attend these sessions that were not compulsory anyway because they were recorded, and she could listen to them if ever she needed clarifications. Student 4 in Focus Group B (male) seemed to attend for emotional and moral support:

> 'I knew nothing about like computers and stuff, but then yeah. But then when we started doing the whole thing, you made us feel comfortable and relaxed me the way you introduced the lessons. The way you explained the lessons every Friday. Yeah, that's when I saw *ukuthi* [*Zulu for "that"*] who would see. This is not as difficult as I thought it could be, ma'am. And yeah, that's what I mean, basically.' (Student 4, Focus Group B, male)

This could explain why there was a group of students who would attend and yet when asked what their challenges are, they would have none. This session gave them an opportunity to see and talk with their lecturer.

Discussion

The focus for this study was on identifying online learning practices that can be attributed to successful acquisition of computer skills. The responses from the focus group provided empirical evidence on the practices of online learning introduced in the literature review that are aligned to the CoI constructs and these are: (1) planning; (2) course design (cognitive presence); (3) social role; (4) communication; (5) interaction (social presence); (6) instruction and learning; and (7) management and administration (Instruction presence). The use of technology is the context from which learning is happening.

The change of attitude contributed to doing all they could to understand the content and instructions. They therefore took advantage of working in groups that had been created for support and Googled for more information and better understanding of the tasks. This is self-regulated learning that helped create a productive learning atmosphere that could be sustained by individuals and in groups.

This research therefore proposes an approach to ICT literacy teaching that does not put the technology on the fore but begins with the occupation. The technology is then brought in to make preservice teachers realise they can become more effective and efficient as they work with and through technology when they teach their subjects in the future. Table 13.2 illustrates how the learning environment should be prioritised if students lacking computer skills will be able to acquire these skills online. They need the ICT infrastructure (the technology) that is consistently available so they can spend as much time as they can on it to develop self-efficacy. In the first column of the table, are the CoI (Garrison et al. 2000) constructs that form the pillar of the pedagogical practices. Next, are the strategies that were used in this ICT literacy course. Lastly are the practices that can be followed to create a conducive environment that promote the acquisition of ICT literacy knowledge, skills and attitudes.

TABLE 13.2: Online pedagogical practices for learning information and communication technology skills.

Online learning environment	CoI constructs elaborated	ICT literacy course strategy	Suggested pedagogical practices
Cognitive presence	Course design	UNESCO ICT-CFT Teaching or subject context-based	• Begin with what students are familiar with • Use different text to present content • Refer students to other resources for further reading • Chunk content • Model quality creation of content
Teaching presence	Instruction, structure, management and administration	Multimedia learning principles	• Explain – new terminology in context and use terminology in instruction • Narration and animation or words and pictures • Graphic organisers or audio • Short formative tasks – quizzes
Social presence	Communication and interaction	Communication strategy	• Create a sense of community through groups (small and tutor) • Some tasks to include group engagement but completed and submitted individually • Moral and emotional support

Key: CoI, community of inquiry; UNESCO, United Nations Educational, Scientific and Cultural Organization; ICT, information and communication technology; CFT, Competency Framework for Teachers.

The practices suggested are generic and can therefore be adapted to equip first-year students with ICT skills they may need for the profession in which they are being trained for. The online pedagogical practices that were used in this ICT literacy course have the potential to create self-regulated learning, but this comes as preservice teachers are made to realise the usefulness and ease of use (Davies 2009) of ICTs in the context of their subject teaching.

Conclusion

The first dataset provided evidence that when students who are victims of the digital divide like those who took this ICT literacy course are provided with a conducive learning environment at faculty (residence with access to ICT infrastructure – technology, learning support – social presence and appropriate course structure and delivery strategy – teacher and cognitive presence) with which they can timeously acquire the desired knowledge, skills and attitudes. It is easier for the students to adopt the skills if they are taught in the context of the profession they are studying for. In this case, students were enculturated into the profession through the tasks they were given. It seems all CoI constructs are critical in ensuring students have a learning experience where they feel they can manage, that is, devoid of fear of technology, and tackle activities in the course with ease. The instructor in this course is an instructional designer who has operated in this field for over ten years. It is therefore recommended that universities or faculties invest in preparing lecturers in course design, so they know how to effectively prepare students online in their respective courses. This study also recommends that ICT literacy courses be taught in the context of the career students are training for. Much care should be taken to ensure the ICTs are introduced in a way that will not intimidate them but scaffold them to desired levels.

Chapter 14

Preservice teachers' challenges in the integration of information and communication technology in Engineering Graphics and Design: A spotlight on sectional drawing

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Abstract

This chapter presents a qualitative study on preservice teachers' challenges in the integration of ICT in an Engineering Graphics and Design (EGD) concept. Fifteen preservice teachers from a Gauteng university took part in the study. Data were collected using semistructured interviews (open-ended e-questionnaire) that were e-mailed to participants because of the coronavirus disease of 2019

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(COVID-19) restrictions. The technology acceptance model was used to better understand barriers about the adoption of blended learning in learning sectional drawing concepts. The results that emerged from the e-questionnaire suggested that preservice teachers struggle with EGD vocabulary when doing sectional drawing using the automated computer-aided design (AutoCAD) software application. The preservice teachers also acknowledge that information communications technology (ICT) is faster, but they prefer manual drawing because the language is more straightforward than with AutoCAD. This chapter suggests that AutoCAD literacies be enhanced in the learning of sectional drawing and other EGD concepts for preservice teachers to adopt ICT integration in learning and teaching (L&T) EGD when they become professionals.

Introduction

Information and communication technology has undoubtedly taken the education spectrum by storm. Most courses and modules have experienced a change of some sort either with how they are taught or configured because of the ever-changing world that is technologically savvy. These changes are not only triggered by the industrial revolutions that keep on changing one after the other but by the demand that the receivers (preservice teachers) in higher education institutions (HEIs) continue to become digital natives.

Literature review and theoretical framework

According to Gellerstedt, Babaheidari and Svensson (2018), there is a need for technological pedagogical competence in order to find sound ways of integrating ICT and refined teaching methods. This would ensure better teaching methods by the lecturers or facilitators and better learning by the students. Gellerstedt et al. (2018) further say that from an optimistic point of view, ICT has the potential to improve L&T methods. According to Mamutse (2016), the use of learning technologies has been hailed as offering a multiplicity of advantages to the learning process. On the other hand, Dargham, Saeed and Mcheik (2013) have shown that learning technologies afford learners the freedom to acquire knowledge and develop skills at their own pace as the learning content is made available to them irrespective of the presence of the teacher. This then would have seen a positive academic performance to all learners and students who use it. The use of learning technologies in teaching and learning is one of the most contentious issues in South Africa's contemporary educational sector. Several studies have looked at the need for the government to introduce learning technologies in the classroom (Bredenkamp 2005:5; Mlitwa 2010; Mlitwa & Nonyane 2008; Nonyane 2011).

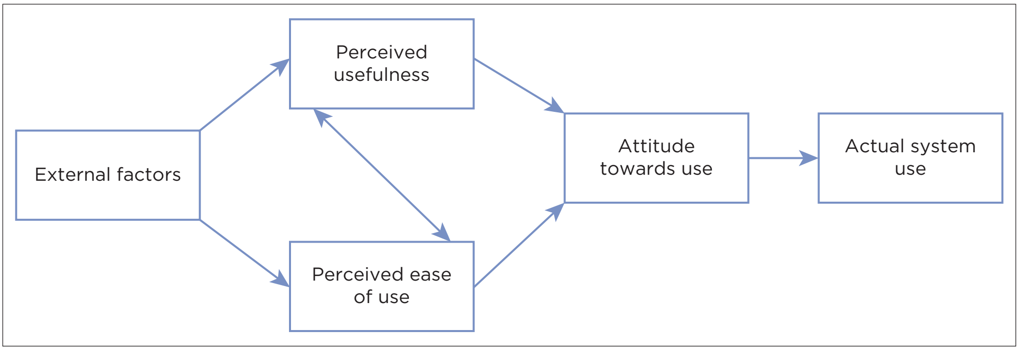
Ma and Liu (2005:6) say that technology acceptance or adoption has received considerable attention in the last decade. Several theoretical models have been proposed to explain end-users' acceptance behaviour.

According to Liao et al. (2018:6), people spend less time reading paper-based publications. Instead, they spend more time sitting in front of the computer consuming whatever it is that they need. Very few people can finish a book from cover to cover, but through online reading, it becomes simple for any book to be read at length (Liao et al. 2018:8). This then shows that electronic gadgets have been the main resources that the public consumes. Tian (2007:4) adds that in the next five to ten years, the influence of the traditional publishing industry on the market will gradually diminish, while a dramatic change in the business model of the publishing industry is expected to come in five to seven years. The mentioned utterances show that digital platforms, irrespective of who consumes them, are regarded as the best platforms where individuals are easily influenced and enticed to pursue them. Therefore, the use of drawing software (AutoCAD) was supposed to be seen as a blessing to the learning of sectional drawing concept in EGD in HEIs.

Conceptual background

As the preservice teachers fall in the category of Generation Y, which is the generation that are born within or with technology, they easily adjust to the use of technology and they are used to software through the video games that they play. This, however, could not always apply to all the so-called Generation Y because of varying socio-economic backgrounds. This opinion was brought by the fact that most if not all preservice teachers of the institutions where this study was conducted do own a digital device or two. Therefore, the technology acceptance model (TAM) was used in this study to better understand barriers about the adoption of blended learning. By blended learning, I simply refer to the fact that EGD concepts are taught and learned *manually* (pencil and a drawing sheet) as well as *technologically* (AutoCAD), which its aim is to make learning and understanding easier through the use of technology. The TAM was developed by Davis (1993) to explain the acceptance of technology. Although blended learning is not a technology per se, technology forms an integral part of this teaching and learning approach. This study utilised the TAM for its investigation because it was deemed an appropriate tool for enabling the researcher to determine the factors that influence preservice teachers in their acceptance of a technology that was new to them (Almobarraz 2007). The TAM has continually been found to be useful, as many researchers, such as Ifinedo (2006:4), Wahid (2007:2), Van der Linde (2009), Chuttur (2009:9), Liu, Li and Carlsson (2010b:5) and Liu et al. (2010a:3) use it.

Davis (1993:5) says that the receptiveness of an individual to accepting and adopting technology is divided into two distinct categories. These categories as mentioned by Tshabalala, Ndeya-Ndereya and Van der Merwe (2018:6) are: the perceived ease of use (PEOU) and the perceived usefulness (PU) of technology, which then determine the user's attitude towards using the



Source: Adapted from Venkatesh and Davis (2000).
FIGURE 14.1: Technology acceptance model.

technology and the decision whether or not to use it. The two categories are interrelated where the PEOU can have a major effect on the PU and vice versa (Tshabalala et al. 2018:8). According to Davis (1993:7), the PEOU and the PU of technology are also influenced by external factors. Vishwanath and Goldhaber (2003:8) mention that these external factors include system features that an individual engages in, situational constraints and user characteristics, whereas Hubona and Geitz (1997) add organisational job categories like support as another factor. Figure 14.1 shows a TAM model that the study used.

Figure 14.1 was used in the study as an underpinning framework. It is interconnected in a way that each concept is related to the next one or vice versa. Therefore preservice teachers were taken through the external factors that they face in using technology towards learning sectional drawing, their PU versus the PEOU, their behavioural use (attitudes) towards using technology and the actual use of technology. This model assisted me in unpacking the gaps that are often hoped to be closed by ICT integration in students' learning. On the other hand Roblyer (1993:7) in Ertmer (1999:2) says that although most teachers today are quick to recognise the importance of using technology in their classrooms, numerous barriers can block implementation efforts. These barriers range from personal fears like what will I do if the technology fails? How will I gain the confidence I need to address technical and logistical issues? How does this software package work? These concerns are also applicable to preservice teachers because AutoCAD is new software that was introduced even before the emergence of COVID-19. The main challenge for it to have been taken up later range from various challenges that emanate from its license, inadequate systems like desktops or insufficient resources to accommodate students.

Why is this an important topic?

With this chapter being written in the COVID-19 season, it became apparent that ICTs were needed to salvage what is left of the 2020 academic year, as well as coping with the normal moving forward. However, most HEIs were not ready to do so when this study was conducted and this is despite the fact that most if not all HEIs have ICT portals that they use to communicate with students, or where the staff members interact. According to Conole and Dyke (2004:2) these portals include Blackboard, WebCT, Sakai, and more interactive ICTs, which include the use of Moodle, which is an online learning platform etc. Conole and Dyke (2014:4) further say 'there is now a range of tools to facilitate information management including commercial products and subject-specific information gateways'. Despite this, there is evidence of slow uptake in the use of these technologies within education (Jones 1996), particularly in concepts that need software. Reasons for this slow uptake could emanate from a variety of reasons, which this study presents, particularly in technical subjects like EGD. Much as I have already alluded to in the previous statement about students and gadgets, the HEI students are digital natives but they do not seem to respond positively to ICT software that they use in EGD. With preservice teachers being the digital natives, I was expecting them to respond positively to the adoption of AutoCAD, which is a drawing (EGD) software, that assists them to draw with ease and faster as compared to the manual drawing of a paper (drawing sheet) and a pencil.

Engineering Graphics and Design as a subject

Engineering Graphics and Design is a technical subject that was previously called Technical Drawing and later called Engineering Drawing, particularly at the former technical colleges, which are now called technical and vocational education and training (TVET) college sectors. Engineering Graphics and Design as a subject consists of linework and shapes as main descriptive features. Those who learn EGD need spatial skills in order to Microsoft Excel in it. Moolman and Brink (2010), define EGD as a language used by technicians in industries and firms to communicate. According to Sorby (2009:2), spatial skills remain the prerequisites that one needs in order to perform well in all the EGD concepts. Engineering Graphics and Design is one of the major subjects that preservice teachers in our South African universities take, especially when they specialise in the mechanical, civil or electrical field of their Bachelor of Education (BEd) degree. Engineering Graphics and Design includes subfields including freehand drawing, perspective drawing as well as sectional drawing, among others. Sectional drawing is regarded as one of the most challenging concepts because a sectional drawing question consists of more details that cut across all other concepts in the EGD curriculum (Brink, Gibbons & Theron 2003).

The sectional drawing concept

According to Khoza (2013), a sectional view is where one imagines that a part of the object has been removed to reveal hidden detail, where in reality nothing has been removed. The main purpose of sectional drawing is to reveal the hidden details in a drawing (Moolman & Brink 2010). This is so because in EGD, we often deal with abstract objects and complex shapes that we could be seeing for the first time, and the reproduction part of those objects often becomes complex. This then requires spatial skill for one to be able to manipulate a sectional drawing question in order to reveal the hidden details. The manipulation requires an extensive knowledge of line types that are used in a sectional drawing question and also the understanding of where the cutting plane is. The purpose of the cutting plane is to give a student an indication of an imaginary location, where the object or a drawing should be cut to reveal hidden details (Moolman & Brink 2010). As the explanation seems too technical and might be difficult to understand, AutoCAD has been seen as one of their source that could ease the challenges in learning the EGD concepts. AutoCAD is a computer-aided software programme created by Autodesk that enables drafters, architects, engineers and other experienced professionals to create 2D and 3D models of solid surfaces and meshes (Moolman & Brink 2010). AutoCAD is widely used and it helps in preventing product failures and warranty issues. With innovative ideas and creative imagination, the user can create realistic presentations with AutoCAD (Moolman & Brink 2010). As AutoCAD is said to be aiding product failures, concrete thinking too is enabled by it. However, the preservice teachers that use it, where this study was carried out, still find sectional drawing challenging despite the technological enhancement in AutoCAD software. This study comes in handy because Sorby (2009:5) says that spatial skills are the prerequisites for the learning of any EGD concept and on the other hand, AutoCAD brings creative imagination and create creative presentations.

Spatial skill and its development

Spatial skill is a fundamental skill for those working and studying in the field of engineering, as well as those individuals in technology professions who work with a diversity of vector graphic tools designing in 3D space and virtual environments (Khoza 2016). In the past, a spatial skills test was popular where students would be given multiple-choice-drawing questions to select the correct shape after a given object is rotated to a certain angle. This became a complex exercise for the students because learning was only limited to one type of skill, which was mental rotation (Sorby 2009:5). Mental rotation, according to Sorby (2009:5), is a process where one imagines visualising objects turning to a certain position or angle. Therefore since the introduction of ICTs, L&T, together with demonstration continues to make the instruction simple because of familiar concepts like virtual reality, Internet of Things as well as 3D printing, to mention a few. Information and communication technology makes the manipulation of the object easy to view and to visualise because of the existence of various programmes and software that are used to manipulate objects. However, preservice teachers in the selected HEIs in the country continue to find sectional drawing more challenging despite the use of ICT (AutoCAD software) in learning the concept. This happens despite these students being regarded as Generation Y children. This then creates a problem because sectional drawing is also applied in other EGD concepts, which makes preservice teachers struggle in them. AutoCAD has been seen as an alternative to manual drawing with the hope that the current generation would be enticed to draw using '*technology*' in order to curb abstract learning of dealing with complex and objects that are seen for the first time. This study then sought to investigate preservice teachers' challenges in using ICT (AutoCAD) when doing sectional drawing.

Research problem

The emergence and the introduction of ICT was seen as a solution to curb teaching and learning challenges in the classrooms, particularly with a great deal of research that touches base on the introduction of ICTs being the possible solutions to absenteeism, poor academic performance and dropout rates in the classroom (Passey et al. 2004). The introduction of ICT was seen as a solution that would bring students back to class because they would be using the same resources or devices that they are used to in their everyday lives. However, the learning of sectional drawing through the use of ICT (AutoCAD) does not seem to help improve academic performance of the concept and other EGD concepts in general. Higher education institutions have computer laboratories where preservice teachers spend time doing their assignments through research and spending time in social media, which these HEIs students use and understand with ease. This interaction is inclusive of communication with their lecturers and exploring within a great deal of digital resources. In these laboratories, AutoCAD software has been loaded for students to practise, work and submit drawing tasks given to them. Engineering Graphics and Design has also been split into manual drawing (where a pencil and a drawing sheet are used) as well as the use of AutoCAD, which is where they use a computer to draw.

Despite all of this, preservice teachers continue to battle with sectional drawing concept even when using AutoCAD software. Their struggles are seen in them not submitting tasks on time or not submitting at all. Those who manage to submit their tasks do not show any academic improvement in sectional drawing concept. Higgins (2003:6) attests to this that naturally, ICT does not improve learning per se and will not make any difference simply by being used. In the past, drawing models were called for in order to make sectional drawing more concrete than abstract (Khoza 2013). Students were given exercises to develop and make models, which they normally draw in EGD classes in order to do drawing practically from what they can see and touch. This study then aimed at investigating the challenges that preservice teachers in an EGD course have in learning sectional drawing and also identify and closing the gaps that ICTs have in preservice teachers' learning.

Significance of the study

The study is important because the findings would assist EGD lecturers to review the use of ICT and other drawing software in sectional drawing and to review how it is used towards the progress of the preservice teachers. This would ensure that preservice teachers would be able to easily progress to the next levels of their academic years by passing all other concepts that are dependent on sectional drawing. The past experiences of preservice teachers in EGD is that they are reluctant to teach sectional drawing and this was because of the challenges that are encountered in their (preservice teachers') understanding of the concept (Khoza 2013). Therefore this study is very important because even preservice teachers' instructional practice confidence might improve during their teaching experience and even after they turn professional. The use of AutoCAD as a programme would also be reviewed or revisited and be evaluated if it is indeed the best tool for preservice teachers in the learning of sectional drawing concept.

Research design

Methodology

This study uses qualitative methods to solicit and interrogate the preservice teachers' views on learning sectional drawing through the use of technology in order to determine the continuing challenges in the concept. Taking consideration of the point that teachers' perceptions are partially related to their beliefs, their assumptions and their experiences (Kuzborska 2011:6), it becomes necessary to examine the teachers' views through interviews. Alluding to similar sentiments Creswell (2014) explained further how this approach focuses on the participants' views, perceptions and experiences in ways sensible to their lives. As my aim was to investigate experiences of preservice teachers on using ICT or AutoCAD in the learning of sectional drawing concept, the study followed a phenomenological approach (McMillan & Schumacher 2006). This assisted me in unpacking the challenges experienced in ICT in EGD concepts, particularly sectional drawing concept that continues to be poorly performed by preservice teachers. Mogashoa (2014) describes a phenomenological approach as the best in enabling the understanding of the subjective experiences of the participant.

Data-collection instruments

Semistructured interviews in the form of an open-ended e-questionnaire included questions pertaining to the preservice teachers' challenges that come with the challenges in using ICT in learning sectional drawing. The reason why the interview schedule are deemed to be questionnaire is that they were made to be open-ended such that preservice teachers could write as much as they could when responding to the statements provided. They had their own disadvantages, however, because as they were e-mailed to the participants, the researcher was unable to probe further questions on the items (questions). These semistructured interview schedules (open-ended e-questionnaire) were e-mailed to participants and answered in writing because it was impossible to have them f2f because of the current nationwide lockdown that is caused by the COVID-19 pandemic. This then did not require ethical clearance from participants because they only took part in the study during their own time; hence, private e-mails were used to send the interview schedule (open-ended e-questionnaire). However, information letters and consent forms were sent to them detailing what the study is about. Issues of anonymity as well as risk were detailed in the letters. It was also stated that should a participant opt out of participation, they would do so without any punishment or compromise. The written interview' (open-ended e-questionnaire) answers were the main source of data analysed in the study. The study sought to respond to the following.

Research aims or research questions

The study aims at investigating preservice teachers' challenges in using ICTs in sectional drawing concept and also to identify the gaps that ICTs have in sectional drawing. In order to realise these aims and to expose the gaps that would eventually be closed, the following research questions were posed:

1. What challenges do preservice teachers experience in using ICT or AutoCAD to learn sectional drawing?
2. How convenient is it for preservice teachers to learn sectional drawing through ICT?

Sampling procedure and data analysis

Convenient and purposive sampling was used to select 15 preservice teachers doing EGD in their third year of their BEd degree programme in a Gauteng university. Convenient sampling was carried out based on the preservice teachers' willingness to take part in the study and for the reason that they do battle with sectional drawing concept. Pseudonyms were used to ensure confidentiality of the preservice teachers. Preservice Teacher 1 was called PST 1 and so on. Ten e-questionnaires were e-mailed back to the researcher, constituting a 67% response rate. The response rate drop could have been a result of preservice teachers studying from home because of the COVID-19 pandemic that forced universities and school to close because of the nationwide lockdown during the undertaking of the study.

The information letters also made it clear that the data collected would be kept in a password-controlled laptop of the research which will be destroyed as soon as the writing process is finished which would be within a period of three years from the time the e-questionnaires were received. Data were analysed using themes and were strengthened using verbatim quotes of the participants for clearer explanation. This was to display the gist of the responses to the problem at hand that the study sought to acquire responses to.

Proposed solutions

The proposed solutions present preservice teachers' experiences in using ICT or the AutoCAD programme in learning sectional drawing concept. The e-questionnaire had seven items that preservice teachers were responding to. In the first item, preservice teachers were asked to respond on their experiences in using ICT or AutoCAD to learn sectional drawing. Most preservice teachers (seven of them) said that it is fun to learn using technology because life is made easy through technology. They however said that using technology and using AutoCAD are two different things because AutoCAD has rules which are difficult to understand. The following themes were derived from their response:

Theme 1: Lack of information and communication technology vocabulary to learn sectional drawing

PST 2 said:

> 'I feel good to see myself on my desktop or laptop doing drawing, but it depends on which topic I will be doing because they vary in complexities. Sectional drawing is the worst concept because when they say follow the cutting plane, I do not know what and where is the object cut. So you can imagine how confused I become when I need to see that feature that should assist me to cut an object using a laptop.' (PST 2, age unspecified, date unspecified)

On the other hand, PST 3 added:

> 'When I am on social media with my laptop or phone, I do understand what it means by an emoji, status, DM (direct message), messenger, etc., but EGD in general is so complex because it has a lot of "language" that most of us do not understand. For example, when an instruction says "project the figure on the given plane" – this is totally confusing and so unclear. It gets worse when I need to articulate that using a laptop.' (PST 3, age unspecified, date unspecified)

PST 6, on the other hand, said:

> 'I believe that doing sectional drawing on my own is more confusing than when a lecturer is in front of me because when the lecturer is with us, we have an opportunity to ask him what a piston is, what a solid is etc.' (PST 6, age unspecified, date unspecified)

Theme 2: Manual drawing is friendlier than AutoCAD

On an item that required preservice teachers to state which mode of EGD they prefer between a manual drawing and AutoCAD, this is how they responded. PST 1 said:

> 'I am not sure which one I prefer because if I have all the drawing instruments and yet I draw an abstract object, the instruments do not help me. And when I use AutoCAD I also might not know how to reveal the inside of the object since sectional drawing aims to expose the inside. So it is just a complicated thing, but with drawing models, which we made ourselves in our workshop during contact classes, I can either use any of the modes provided that I know the instructions and the tabs that I need to punch in my laptop.' (PST 1, age unspecified, date unspecified)

PST 2 said:

> 'I prefer manual drawing where I use a drawing sheet, clutch pencil and an eraser because it is easy for me to erase when I made a mistake. With AutoCAD, I once deleted the entire drawing that I had started because I did not know the tab to choose to remove a line.' (PST 2, age unspecified, date unspecified)

PST 4 commented:

> 'I like manual drawing because when I do sectional drawing, there is always a concrete model of what I am drawing on a side which the lecturer always gives us. I also noticed that even in CAPS level, there is always a clue of what the end product is, so I believe that with AutoCAD, I could even be faster should perhaps a YouTube video accompany what I am drawing or maybe a clue is given like in a copied question or prescribed book that we have.' (PST 4, age unspecified, date unspecified)

PST 5 also added:

> 'I honestly prefer AutoCAD because I often check what is on YouTube which is helpful at times. But the issue happens when I make an error and deleting could make the entire drawing disappear. So I end up submitting whatever I was working on back to the lecturer with errors being scared to lose the entire drawing.' (PST 4, age unspecified, date unspecified)

PST 7 echoed:

> 'AutoCAD is the way to go but I ensure that I plan accordingly and read the instruction of the question and see how quick I can collect the marks, because making amendments on AutoCAD, you need to be careful because I find the tools too sensitive, hey.' (PST 7, age unspecified, date unspecified)

Theme 3: AutoCAD or information and communication technology speeds up tasks submissions

Preservice teachers were also asked to respond on the efficiency of AutoCAD in ensuring that tasks are quickly submitted, and all of them agreed that, through AutoCAD, it is quick to submit tasks. This is how they responded. PST 1 said:

> 'If I understand what the question wants and know all the tabs that are in the programme, a 75-marks sectional drawing can be done in 20 minutes.' (PST 1, age unspecified, date unspecified)

PST 3 said:

> 'AutoCAD is definitely faster but I normally submit my tasks with principal mistakes because of not knowing how I can modify the drawing. It becomes sad when my mistakes affect the correctness because in EGD correctness weighs 60% of each question.' (PST 3, age unspecified, date unspecified)

PST 6 also added and said:

> 'Much as we like AutoCAD classes, we do enjoy them when we know that the lecturer is available and in front of us leading the way. But when he says we should go by ourselves to draw a certain sketch, we often get so confused on petty things like failing to plan the drawing and I was telling my friend that we get 'beaten' by the AutoCAD language. This is because we have not received a full training on the software, we always did it in passing and now we have to use it because COVID-19 makes us stay at home.' (PST 6, age unspecified, date unspecified)

Theme 4: Information and communication technology does not assist in spatial skill development

Preservice teachers also were asked whether AutoCAD or ICT integration does assist in spatial skill development. The following is how some of them responded. PST 1 said: 'Not really. I still need a drawing model or a clue that is always given when we use an instrument to draw.'

A second-year male, PST 3, commented and said:

> 'Imagine when we draw a sectional view of a piston, even if you have a car it is way difficult to figure out how a piston looks like when cut so I need a drawing model however a drawing model would work when I draw by pencil because using AutoCAD I find it hard to apply a physical model into a computer.' (PST 3, age unspecified, date unspecified)

A second-year male, PST 4, also shared their view and said:

> 'I believe that a spatial skill is something we are born with because if I visualise an object better when I have a drawing model, why cannot the same model help me when I use AutoCAD or Turbo CAD?' (PST 4, age unspecified, date unspecified)

A second-year 24-year-old female, PST 8, echoed similar sentiments to what PST 4 had and wrote:

> 'In my first year, our lecturer gave us a spatial test; it's a pity I forgot its name. In that test we went through sketches that needed to be rotated, and according to the lecturer, only 15% of us passed that test and then we started developing drawing models in our workshop, and we concentrated on making objects that were in our EGD books; that exercise helped us with visualization and spatial skill. So I believe that in each and every level we need such test, which would match the standard of that particular level. So to me, AutoCAD does not assist in visualisation.' (PST 8, 24 years old, date unspecified)

These responses show that preservice teachers have multiple and varying challenges towards the use of ICT or AutoCAD in learning sectional drawing concept. Their challenges with the ICT vocabulary, their preference for manual drawing over drawing using ICT, their acknowledgement that AutoCAD enables them to fast-track tasks submissions and that spatial skills are difficult to develop through ICT; expose challenges that they have in learning sectional drawing concept, which ought to be attended to.

Discussion

These responses make quite a significant submission of how preservice teachers learn sectional drawing. As it is quite a norm that most university students are so embedded in technology usage in the form of operating and enjoying their digital devices, the learning part sheds a different version from the normal narrative.

Challenges in information and communication technology vocabulary

Theme 1 points out that AutoCAD or ICT in sectional drawing has its own vocabulary which preservice teachers fail to understand. This sentiment is echoed by Higgins (2003:6), who says that, naturally, ICT does not improve learning per se and will not make any difference simply by being used. Dargham et al. (2013) have shown that learning technologies afford learners the freedom to acquire knowledge and develop skills at their own pace as the learning content is made available to them irrespective of the presence of the teacher. However, this study found the opposite of what Dargham et al. (2013) alluded to because it seems like preservice teachers are left on their own without enough vocabulary support to learn on their own pace. Ertmer (1999:6) further says that barriers to change one's normal practice in technology integration are 'the extrinsic and intrinsic' factors that affect one's innovation. Thus, first-order barriers to technology integration are described as being extrinsic and include lack of access to computers and software, insufficient time to plan instruction and inadequate technical and administrative support.

Preservice preference in manual drawing than AutoCAD software

Theme 2 presents that preservice teachers find manual drawing better to do as compared to AutoCAD or ICT type. This is because in manual drawing exercises, there are hints of how final products should be which is not the case with AutoCAD. According to Davis (1993:6), the PEOU and the PU of technology are also influenced by external factors and the external factors in turn influence the attitude towards using technology, thereby leading to the actual use of technology or the decision not to use technology. Therefore as preservice teachers could only access the AutoCAD software at their respective campuses, they are often faced with external factors of lack of access to the software, which delays them on doing the tasks meticulously. This means that preservice teachers find ICT integration in sectional drawing a hindrance because of external factors where a clue is not provided like in manual drawing.

Information and communication technology enables faster task submission than manual drawing

This would also respond to theme 3 where preservice teachers agreed that ICT integration speeds up submission of tasks provided they receive better methodological instructions. However, in manual drawing, students often come across various challenges where some lose their drawing sheets or use inadequate line types, which end up getting them penalised displaying a totally wrong sketch because of lack of spatial skill.

Challenges in spatial development through information and communication technology instruction practice

In theme 4 preservice teachers still believe that ICT integration does not assist in spatial skill development. Tshabalala et al. (2018) say that the receptiveness of an individual to accepting and adopting technology is divided into two distinct categories, which are PEOU and the PU of technology. The two concepts are said to have an urge to influence someone's attitude towards the use of technology separately, but they still remain interrelated where the PEOU can have a major effect on the PU and vice versa to have students responding the way they have in this study. On the other hand, Gellerstedt et al. (2018) say there is a need for technological pedagogical competence in order to find sound ways of integrating ICT and refined teaching methods. This pedagogical competence in this regard is needed by both lecturers in order to teach preservice teachers and preservice teachers themselves to be able to know it for the sake of their teaching experience. This should come in the form of TK that preservice teachers need to ensure better learning from classroom instruction. According to Mamutse (2016), the use of learning technologies has been hailed as offering a multiplicity of advantages to the learning process, but this would need a strong foundation from instructional practices in the classroom. Therefore, the main gap that this study found is that much as preservice teachers are exposed to digital devices, they lack the vocabulary to use them, particularly in the AutoCAD programme. Their challenges are exacerbated by the lack of training that their lecturers expose them to using this AutoCAD software. This then exposes their challenges in mastering sectional drawing, which is an abstract topic in EGD.

Conclusion

The study sought to investigate the challenges that preservice teachers have in ICT integration in learning sectional drawing in a university course. Information and communication technology is seen as a major drive to the youth, most of whom are preservice teachers in this study. However, preservice teachers do not seem to be in favour of ICT use in learning sectional drawing. Much as they do appreciate learning sectional drawing through technology, they battle with ICT and sectional drawing vocabulary. They do not seem to understand all the basic features that make part of the fundamental of ICT integration in the form of AutoCAD programme. The study found that much as preservice teachers are involved in technology use daily, they find it not compatible in the learning of sectional drawing. Most say that they prefer manual drawing because of the clues that their drawing sheets and prescribed textbooks come with. They suggest that should lecturers assist them with AutoCAD programme clues, learning will no longer be a challenge to them.

External factors like lack of drawing models also are a hindrance to preservice teachers towards learning sectional drawing. Therefore it would be important for drawing models to be made available in the classroom so that abstract topics are made understandable. AutoCAD vocabulary is mandatory as a foundation to AutoCAD learning. One would have thought that because we teach the digital natives, it would be easier for them to adapt to any technology use in their learning, which is not the case. Further investigations need to be undertaken into the relationship of technology use in everyday life and the integration ICT in education. AutoCAD should be coupled with an alternative technology that can promote ease of use for preservice teachers. This would ensure that there is a variety of tools at the preservice teachers' disposal and enable them to select what they prefer for their studies.

New instructional practices should be embedded in teaching sectional drawing. Lecturers at university level should ensure that sectional drawing vocabulary as well as that of ICT or AutoCAD be infused together to ease the learning of sectional drawing. This could be carried out by tutorials where AutoCAD programme is made to be a lesson so that preservice teachers can understand the ins and outs of it. It should also be a practice that in each level, spatial skills test be given to preservice teachers to better gauge their knowledge at that particular level.

Declaration

This chapter is my own original work and all sources used have been acknowledged by way of references in the text and in the list of references. The chapter is free from plagiarism and it has already been reviewed twice to the satisfaction of the panel. This chapter targets preservice and in-service teachers in the Technical and Technology education field as well as policymakers who are responsible for the development of technology education and e-learning.

Part 3

ICT integration in language teaching in teacher education

Chapter 15

Supporting student cognition of scientific knowledge through multilingual e-learning pedagogy

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Abstract[14]

The emergence of COVID-19, an infectious disease spread through human-to-human transmission, in the year 2019 resulted in the immediate suspension of traditional contact classes the world over in a bid to contain the wide spread of the virus. The COVID-19 pandemic disrupted educational routines leaving educational institutions with only one option: e-learning. E-learning is a technological pedagogy which supports teaching and learning through the

14. Sections of this chapter represents a substantial reworking and amalgamation of the following three publications: Charamba (2019b, 2021a, 2021c).

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use of electronic mail, the Internet, the Internet and can either be synchronous or asynchronous. Through a sociolinguistic lens embedded in the funds of knowledge and Freire's *Critical Pedagogy*, this qualitative study sought to explore the role language plays in the e-learning of 20 undergraduate science students at a university in South Africa. The e-learning lessons were delivered through videos, animations and narrated slides in English with subtitles in isiZulu and Sesotho languages. Data were collected through focus group interviews held via Microsoft Teams. The study presents positive cognitive and sociocultural benefits of multilingual pedagogy in e-learning and recommends its adoption in HE.

Introduction

New technologies have the potential to support education and provide opportunities for effective learning in ways that have not been possible before. Information and communication technology integration in education has the potential to be influential in bringing about changes in ways of teaching. However, this potential may not easily be realised unless educators tailor-make their curriculum to cater for all students. Several factors have resulted in increased intra- and inter-state movement of people culminating in overcrowded multilingual communities. Education has not been spared as this mobility has resulted in bloated classrooms, placing a huge strain on available resources such as laptops, thus compromising the quality of education. Institutions of education have also witnessed an increase in the enrolment of students with diverse linguistic and cultural backgrounds. In the year 2020, the situation was worsened by the emergence of COVID-19, an infectious disease spread through human-to-human transmission.

The education sector was not spared effects of the COVID-19 pandemic as it led to immediate suspension of traditional contact classes in a bid to stop the wide spread of the virus disrupting educational activities of over 400 million students worldwide, threatening their future education rights (UNESCO 2020). This left institutions with only one option: online teaching and learning. This means instructional practices that were previously conducted through f2f pedagogy in traditional classrooms switched to online (Allo 2020). This led to many institutions circumfusing the concept of e-learning through E-campuses. South Africa already had the White Paper on e-Education (DBE 2004) with the primary goal to transform education through the integration of ICT. To achieve this, the need to prepare teachers for ICT integration cannot be overlooked as they are the major players in this equation. Thus, teachers' training, both at the pre and post-service levels, is critical. The other hindrances being the scarcity of technological devices, especially in underprivileged communities as well as the language used on online applications. The language of instruction in the country is mostly English, which has repeatedly been identified as a contributing factor to students' academic underachievement

(Probyn 2019). Using qualitative data, this chapter explores the efficacy of multilingual e-learning pedagogy in HE.

E-learning in higher education: A global résumé

The evolving digital technologies coupled with an increasing interest in computerised delivery of HE courses have resulted in e-learning through electronic mail, the Internet, the Internet and multimedia. E-learning is a learning system that facilitates teaching and learning to locations away from the traditional classroom with the help of electronic resources such as computers, mobile phones and tablets. The educator and students can make use of video, audio, multimedia communications, or some combination of these in the learning process. E-learning applications and processes that can be used for instructional purposes include web-based learning, computer-based learning, virtual education opportunities and digital collaboration. The educator can deliver the educational content through the Internet, intranet or extranet, as audio or visual tapes, as narrated slides, satellite television and CD-ROM (Wani 2013). The student accesses the content at their own convenient time and place (Charamba 2021b). Through e-learning, the transfer of skills and knowledge is enabled through technology. Because of its convenience, e-learning plays a vital role in education during the COVID-19 lockdown and has the potential to change the HE landscape.

A study by two Stanford University professors in California in the 1960s reports on positive academic benefits of using technology for instructional purposes. The two used computers in the teaching of Mathematics and reading to elementary school students and suggest a remarkable improvement in their understanding of mathematical concepts and reading comprehension (Gray 2011). In the study, students were taught synchronously and asynchronously. Some of the lessons were in real time, with the lecturers presenting live lessons through computers. With asynchronous lessons, the lecturers prerecorded their lessons and uploaded them on learning sites for the students. The students would then access the lessons and other learning resources at their own time. Results from William D. Graziadei's online computer-delivered lectures, tutorials and assessments report on improved student engagement and performance. Here, the lessons were completely asynchronous. The lecturer prerecorded the lessons and uploaded them onto the university's learning portal. Students accessed the learning materials, went through them and answered any activities accompanying the different lessons.

The researcher suggests a substantial improvement in student performance as a result of e-learning pedagogy (Graziadei et al. 1997). Graziadei posits that e-learning resources are easy for students to use and maintain the learning resources because they will be stored on a device, unlike in print form.

The other advantage is their portability allowing students to move around with the learning materials in their hands or pockets. The study also suggests that the improvement in academic performance was because of the permanent availability of learning resources on sites accessible to the students. This gave students the opportunity to visit and revisit the materials as many times as they wished.

This way, the student literally has the whole library in their hands. They are also replicable, scalable, having a high probability of success with long-term cost-effectiveness and enable the educator to deliver content in various forms including animations (Wani 2013). One web-based learning media software that displays many animations and cartoon character is PowToon. With this software, one can add background sound, music and even recording sound for specific purposes to their presentation (Frisnoiry, Darari & Refisis 2019). One of the greatest advantages of e-learning is that it helps students with and without disabilities develop their social skills through audio-visual instruction through the use of videos, games and team-based activities without having them feel awkward among other students (Mamattah 2016). However, some of these applications have a very limited range of avatars, which are not representative of racial, linguistic and cultural diversity. Such issues of critical literacy and representation must be taken into account when one is developing their e-learning curriculum, as they qualify the usefulness of such applications. Also, not all educators are tech-savvy and training or retraining of such educators can cost money that several governments, especially in developing countries, do not have.

The successful integration of ICT into the learning environment largely depends on the ability of educators to structure the curriculum in new ways, to merge technology appropriately with inclusive pedagogy, develop socially active classrooms and encourage cooperative interaction and collaborative learning.

A study by Frisnoiry and colleagues reports on improved academic performance among Mathematics Learning Method students at an Indonesian university. Based on their study, they argue that e-learning enables students to access learning materials anytime and anywhere. Students are also motivated as they receive materials in different forms such as animations, videos and journal articles (Frisnoiry et al. 2019). Students have the opportunity to repeatedly revisit the learning materials as many times as they want (Seago, Koellner & Jacobs 2018). The permanent availability of online study materials emerged the most common advantage of e-learning in a study conducted by Vitora, Mislinawati and Nurmasyitah (2018). The participants attributed their improved academic performance to revisiting the course materials until they understood the concepts. In traditional contact classrooms, the student will have to rely on the educator's explanations, printed materials availed and the notes they would have taken during class.

Direja (2017) reports on the effectiveness of e-learning in a Communication Science Undergraduate Study Program. The study suggests improved computer and communication skills among the undergraduate students who participated in the study. There was also an improvement in the students' literacy levels and a reduction in the course dropout rate. E-learning provides education round the clock to a large number of students, unlike the traditional brick-and-mortar classrooms that limit student numbers because of limited capacity. In a way, it eliminates the barriers of time and distance, allowing the student to take responsibility for their own learning schedule.

Through e-learning, universities can adopt either a synchronous or an asynchronous model to teaching and learning (Charamba 2021a). The asynchronous model is so flexible that the educator and student do not communicate in real time with each other for various reasons. The educator posts the instructional content to be accessed by the student at their convenient time. These can take the form of videos, texts, or narrated Microsoft PowerPoint slides. In such cases the educator-student dialogue mostly takes place on discussion fora or through e-mails. The synchronous learning model caters for scheduled real-time verbal or nonverbal dialogue between the educator and the student through audio and visual media such as texting, video conferencing and virtual classrooms (Seago et al. 2018).

Given its numerous advantages, HEIs need to leverage e-learning to improve the teaching and learning experiences of all students across the curriculum. Educators and students can meet in virtual classrooms with the provision of learning materials being carried out online. E-learning provides a platform to shift from the days when education was socially-oriented, students expected to carry bags full of learning resources, attending lectures in specified rooms and sit in designated ways and positions, during specific times. However, Dowling, Godfrey and Gyles (2003) argue that e-learning can only improve the quality of education if students have proficiency in the language through which educational materials are delivered.

However, these studies overlooked some of the most important conditions for effective e-learning. Not every student can afford technological devices to use for their e-lessons especially in the underprivileged communities. In these communities, devices such as laptops, tablets and mobile phones are scarce. In families where these are found, they are normally shared among several members of the family or families, making it difficult for the student to use them to the fullest. Another factor, also, is that technology is not politically or culturally neutral. E-learning applications and services are provided by large multinational corporations, which are ruled by neoliberal ideologies that prioritise profit and are also profoundly colonial. So, any engagement with e-learning, particularly for universities in developing countries, must involve careful negotiation of discourses of development and advancing technology and keeping up because those function to colonise and control our educational endeavours. We must leverage the affordances of e-learning that will empower our students, while vigorously interrogating and critiquing power imbalances and redesigning e-learning so that it works for us. This includes redesigning e-learning to include students' linguistic repertoire through multilingual pedagogy.

As in any other country, COVID-19 surfaced in South Africa about the engrained neoliberal contouring of the country's socio-economic landscape including the education sector. The education sector has already been characterised by perverse neoliberal principles, an obsession with competition, a culture of performativity and surveillance. The present study sought to explore the role language plays in the teaching and learning of undergraduate science students and ways in which educators can capitalise on student multilingualism in e-learning at a South African university. When ICT is integrated into lessons, students are supposed to become more engaged in their work as technology provides different opportunities to make it more fun and enjoyable in terms of teaching the same things in different ways. However, as alluded to elsewhere in this chapter, no e-learning applications are in African languages, ignoring the potential positive impact these languages might have on students' learning. Institutions of education have a need to adopt an information-literacy curriculum; and students have a need to develop their ICT and thinking skills and take responsibility for their own learning. Such needs would be met within a '*language appropriate*' technology-enabled teaching and learning environment that emphasises student self-direction and self-regulation.

Theoretical framework: Critical pedagogy and funds of knowledge

During his time working with illiterate Brazilian peasants, one of the world's first philosophers whose work is considered one of the foundational texts of CP by proposing a pedagogy with a new relationship between the educator, students and their experiences and society, Paulo Freire held the experiential conviction that the traditional pedagogy dehumanised students by treating them as empty vessels (Charamba 2021b; Freire 2007). In his pedagogical model of CP, he suggests that true transformation and decolonisation in the classroom can only be realised when both the educator and the student acknowledge each other's different experiences and expertise they bring into the classroom and view them as instructional resources. In the process of *conscientização*, the acknowledgement and embracing of a student's linguistic disposition and funds of knowledge they bring into the educational spaces is the first step towards humanisation as it creates equality and fosters meaningful discussion between educator and student (Freire 2007, 2014).

The theory of funds of knowledge recognises the potential associated with the knowledge and experiences resultant from students' active participation in multicultural, multilingual and multigenerational households and community activities (Gonzalez 2005). Students, according to this theory and in consonance with Freire's *CP* do not enter the classroom as blank slates (Freire 2007). In this regard, the funds of knowledge theory posits that effective pedagogy should be linked to local histories and community contexts with regards to language and culture (Charamba 2021b; Gonzalez, Moll & Amanti 2005). The theory recognises students' households as 'repositories of knowledge', which can be transferred to school contexts and embedded in the students' funds of knowledge is their diverse linguistic repertoire which should also be incorporated into the classroom situation through multilingual pedagogy (Gonzalez et al. 2005).

South African legislative policy endorses dynamic pedagogical strategies that integrate the use of multiple languages for instructional purposes. These commitments and recommendations for multilingualism in HE are made in statutes such as the *Higher Education Act* (1997), the *Language Policy for Higher Education* (2002) and the *White Paper on Post-Secondary School Education and Training* (Department of Higher Education and Training [DHET] 2015; Maringe 2013; Mkhize & Ndimande-Hlongwa 2014). Although the country's language legislation and policy frameworks endorse multilingualism, education in South African HEIs largely still follows a monolingual route whose roots lie in the colonial era and does not value the multilingual nature of these institutions (Charamba & Zano 2019). All HEIs in the country have either English or Afrikaans as the language of L&T, although the two are the home languages of a combined 24% of the country's total population (Statistics South Africa 2019).

Purpose of the study

Current discourses about education amid the COVID-19 pandemic are marred with an obsession by institutions to try and save the academic year, with ICT integration in education being the only viable option. In view of this, it is imperative to investigate how educators can integrate multilingual pedagogy in e-learning. Besides being required to have the appropriate ICT knowledge and skills and be able to integrate ICT appropriately in teaching, educators should also devise ways that encourage maximum efficacy of ICT integration into their lessons. In this study, the provision of e-learning to multilingual students has been examined through a sociolinguistic lens embedded in the funds of knowledge and Freire's CP. The study examines the role language plays in the teaching and learning of an undergraduate science course at a university in Johannesburg.

The lectures on mechanics and Newton's laws of motion were taught through e-learning consistent with health care standards established to restrain the escalation of COVID-19 in the country. The language of instruction at the university is English. In accordance with the theories cited elsewhere in this chapter, deficient proficiency in the instructional language can become a consequential hindrance to good academic performance in science education, especially as many language minority students keep grappling to meet the academic demands of the scientific texts (Charamba 2019b). Students' performance 'in this and other related courses has not been encouraging at all mostly because of the language used during the lessons and in their texts' (Mojalefa, Male student, aged 23; Interview 20 May 2020).

Research questions

The study sought to answer the following questions:

1. How does the use of multiple languages in e-learning affect science students' academic performance?
2. How can educators incorporate students' multilingualism in e-learning?

Embedding multilingual pedagogies into e-learning

A body of research in science education suggests that low proficiency in the language of instruction is one of the major causes of low academic performance among students whose home language and language of instruction differ (e.g. see Charamba et al. 2019; De Costa 2019; Probyn 2019; Zhang et al. 2020). Further research also demonstrates that the use of more than one language in the same lesson has positive academic, social and emotional effects (e.g. see García 2019; Iversen 2020; Li 2018; Lin 2019).

In the present study, lectures were delivered through videos, animations and narrated slides in English (the university's language of instruction). The e-learning material also had subtitles in isiZulu and Sesotho languages. The two African languages were chosen because, according to student demographics, 90% of the 20 participants spoke isiZulu or Sesotho as their home language. The other 10% were English home language speakers. For example, in Excerpt 1:

English voice note: Let us begin by seeing what a force does to an object

Sesotho subtitle: *A re qaleng ka ho bona hore na matla a itseng a etsa eng ho ntho e itseng*

isiZulu subtitle: *Ake siqale ngokubona lokho amandla athile akwenzayo kokuthile*

English voice note: Force makes an object move

Sesotho subtitle: *Matla a etsa hore ntho e sisinyehe*

isiZulu subtitle: *Amandla abangela ukuba into ihambe*

English voice note: Force can stop a moving object

Sesotho subtitle: *Matla a ka emisa ntho e tsamayang*

isiZulu subtitle: *Amandla angamisa into enyakazayo (ehambayo)*

The students were also provided with text study materials written in the three languages (English, Sesotho and isiZulu). For example, in Excerpt 2:

English: Apply
Sesotho: *Sebedisa*
isiZulu: *Sebenzisa*

English: Mass
Sesotho: *boima*
isiZulu: *isisindo*

English: Speed
Sesotho: *Motsamao*
isiZulu: *Isivinini*

In cases where there was no direct translation from English to the two African languages, the scientific terms were explained in the closest possible words, for example, in Excerpt 3:

English: Vector
Sesotho: *ke ntho e nang le tselale boholo kappa bonyane*
isiZulu: *yinto enokuningi noma okungenani okuthile kuyo*

At the end of the course the students were given a multilingual assessment written in the three languages used throughout, for example:

Excerpt 4:

English: Which ONE of the following formulas is a product of one of Newton's laws?
Sesotho: *Ke efe ea mekhoa e latelang e hlahisitsoeng ke melao ea Newton*
isiZulu: *Yiphi kwamanye amafomula alandelayo angumkhiqizo wemithetho kaNewton*

1. $V = \sqrt{\frac{2GM}{R}}$

2. $S = v_0 t + \frac{1}{2}at^2$

3. $y - y_1 = m(x - x_1)$

4. $\rho = q / v$

Method

Data-collection

The study was qualitative in nature and data were collected through interviewing the undergraduate students in the researcher's e-tutorial group. The group had 20 students who all volunteered to partake in the study. Of the

20, 12 were isiZulu home language speakers, six Sesotho, and two were native English language speakers. All ethical considerations were observed, and students chose pseudonyms with which to be called during the study. The focus group interviews were conducted through Microsoft Teams. Besides the advantage that the platform is zero-rated, Microsoft Teams also gives the option to record and transcribe proceedings while the meeting is in progress, thus ensuring data is not lost.

The data were analysed using a combination of both inductive and deductive approaches (Bryman 2015). We extracted deductive codes from the scholarly writings we reviewed and these included: e-learning, meaning-making, multilingualism and epistemological access (Charamba 2019a, 2021a; Karlsson, Larsson & Jakobsson 2018). An analysis of the interview transcripts led to the development of inductive codes (McMillan & Schumacher 2010). Recurring patterns were identified to construct emergent conceptual categories and themes (Lemke 2012).

Findings

The COVID-19 pandemic compelled the education sector to embrace ERTL. This mode requires well-established online learning platforms to enable successful delivery of curricula. The urgency exposed some of the challenges of and epistemological access, chief among them being student support in e-learning. After having analysed the qualitative data generated from the interviews the emerging themes are presented and discussed.

The interface between proficiency in the language of instruction and academic achievement in undergraduate science education

Despite multilingualism being acknowledged and scripted in current South African legislatures cited elsewhere in this chapter, monolingualism has remained the default educational practice in most universities around the country. All but two South African official languages are actively excluded from HE curricula (Charamba 2019b; McKinney & Tyler 2019). Multilingual practices have always been observed within the country's universities, presenting an undisputable case for the use of multilingual communication practices that blur boundaries between different languages (Charamba 2021a). While many studies on multilingual pedagogy in education have critiqued the prevalent monolingual bias, very few frameworks have been developed to account for the ontological, epistemological and methodological framing of these practices with regard to e-learning (Sun & Chen 2016).

All 20 respondents in the tutorial group indicated they had problems with language in science education. This emanated from the decontextualised nature of the language used as well as the presence of some non-English terms found in the curriculum. In agreement with this notion was Mmabatho, who highlighted that:

> 'I am a Sotho and English is my third language so imagine being taught in your third language and expected to excel. It's not possible. The English I speak during conversations with my friends is different from the one we encounter in the science texts. The English in those texts is too deep and I struggle to understand it. That's the major reason I don't do well in science.' (Mmabatho, female student, 25-years-old)

Mmabatho's response, as well as comparable ones from other participants, confirm Cummins' claims that there is a correlation between proficiency in the language of instruction and academic performance. Cummins (2008) identifies two levels of language proficiency: basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP). The BICS concept represents the language of a natural, informal conversation that the students use on the playground during any informal conversations (Charamba 2019b), such as that referred to by Plaxedes in her response. Cummins refers to this everyday conversational ability as context embedded or contextualised and does not help much in the classroom. To do well in the classroom, a student makes use of the CALP.

This is the type of language proficiency needed to read and understand scientific literature, participate in scientific discussions and to provide written responses to science assessments (Cummins 2008). This therefore means students who have not yet developed this much-needed proficiency (CALP) are, according to the students' responses at a disadvantage in the monolingual educational set-ups. Most students who are taught through a language different from their home language do not have the necessary CALP, resulting in them underperforming academically (García & Otheguy 2020). Although some English minority students can converse in the language, the type of language found in their textbooks is more difficult and advanced than the basic one they use in informal conversations.

A recent body of research on possible causes of underachievement among university students suggests the mismatch between students' home language and the language of instruction to be the main cause (e.g. see Hua, Li & Jankowicz-Pytel 2020; Iversen 2020; Olivares-Orellana 2020; Vallejo & Dooly 2020; Zhang et al. 2020). In the present study, responses from undergraduate students confirmed how language presents them with difficulties in understanding scientific concepts and answering questions because of the complexity of the language of instruction used. These students are faced with the double challenge of acquiring scientific knowledge and skills through a language they have low proficiency (Charamba 2021b; Cummins 2008). The interview responses of the present study are also partly confirmed in my previous studies and in some other studies conducted globally (e.g. see Charamba 2019a, 2019b; Charamba & Zano 2019; Charamba et al. 2019;

Karlsson et al. 2018; McKinney & Tyler 2019; Monteagudo & Muniain 2019; Msimanga, Denley & Gumede 2017; Song 2019).

Multilingual pedagogy as a scaffold for teaching and learning of science through e-learning

90% of students in the study are taught in a language different from their home language. The critiquing of monolingual pedagogies and the emergence of perpetual academic underachievement of minority science students has resulted in researchers paying attention to multilingual education (Li 2018), that is, the acknowledgement and inclusion of multilingual students' entire linguistic repertoire in the classroom. Interview responses from all students suggest that multilingual pedagogy offers science students increased possibilities for scientific knowledge comprehension. Several students stated the use of more than one language motivated them and:

> '[*F*]or the first time I enjoyed my science lessons because of the use of Sesotho translations. My English is not good at all hence I don't understand most of the work taught through English. Yes, I do speak the language but it's informally not the educational language. The Sesotho translations made me understand everything and I even got a good grade for the end of course assessment task.' (Nomphilo, female student, 23-years-old)

Expanding on Nomphilo's response, Claris said:

> '[*T*]here is no way I will fail any assessment on this topic. There's no reason at all because was I taught in my language. Those handouts also written in isiZulu just made my day. This was the best thing to come out of the year 2020. This made everything easy for me. Being taught in English only is a problem.' (Claris, female student, 22-years-old)

Multilingual pedagogy:

> '[*G*]ave me the support I really needed. It's not easy to study on your own with no one to explain to you. Actually this is the way we explain concepts to each other as students, we use our home languages.' (Mojalefa, male student, 23-years-old)

Here Mojalefa refers directly to and points out one disadvantage of learning. The students bring out one of the disadvantages of flexible anywhere-anytime online learning, in that the student is isolated from class discussions and from support from peers and the teacher. The only support the student can receive is the provision of multilingual resources as these tap into the students' linguistic repertoire. According to Mojalefa, students always re-explain concepts to each other in their home languages.

The students' responses suggest that lessons and learning materials in languages students fully understand facilitate effective learning. The present study suggests that for instructional effectiveness, e-lessons and learning materials should be in more than one language. In situations where the educator is not conversant in the students' language, they can enlist the services of their colleagues to translate for them. One can also make use of Google Translate. However, when using this site, it is always advisable employ the 'Back Translation' option. This verifies the initial translation. Through multilingual e-learning, students understand the concepts well and

> '[*T*]he way I understood this topic made me feel motivated and look forward to the next one. I normally struggle with answering assessments but it was a different story this time around. At times I submit my work late or don't submit at all because of challenges presented by the English language.' (Kayla, female student, 20-years-old)

Because it facilitates deeper understanding of scientific concepts, multilingual pedagogy in e-learning also motivates students and, according to students' responses and data collected from the assessment task, reduces the number of late- and nonsubmissions. At the end of the course, all students submitted their tasks well ahead of the due date. Also, there was a noticeable improvement in student engagement during the e-tutorials. In the majority of monolingual HE science classes students are passive listeners because of the linguistic barrier caused by their low proficiency in the language of instruction (Charamba 2021b) in cases where the language of instruction is different from the students' home language (McKinney & Tyler 2019; Preece 2019). Such discrepancy also depicts the printed academic matter peripheral to the majority of students unless penned in a language they fully understand.

■ Discussion

The integration of ICT into education has been receiving considerable attention from various institutions worldwide, making it topical among parents, educators, policy planners and researchers. In South Africa in trying to improve the standard of education, the government enacted an e-education policy that saw the integration of technology in education. As is the case with South Africa, there is a noticeable increase in global initiatives towards improving the quality of education through ICT integration, with an examination of the language of instruction being one of them as this (LoLT) has been identified as a barrier to effective online learning (Allo 2020). In South Africa, the most common LoLT is English.

While English has assumed hegemony as the world language, the pronounced controversy on how best to educate non-English speakers in a world dominated by English has been going on since time immemorial as most institutions of education worldwide remain and are increasingly becoming more culturally and linguistically diverse because of globalisation nurtured by improved technological communication and global migration. This evidently contradictory situation has brought about both tensions and new ways of thinking about the e-learning of science students in multilingual contexts. The emergence of multilingual instructional programmes operating in various countries across the globe indicates a shift from monolingual pedagogy to embrace the use of multiple languages in education.

There is a need for educators and planners to explore ontologies, epistemologies, technologies and cultural banks to arrive at new policy frameworks that will improve the e-learning of multilingual science students. In so doing, countries can come up with open ideological spaces in which the language policy enables the use of multiple languages in e-learning and other educational and social domains. As alluded to elsewhere in this chapter, research suggests that being taught through a language different from one's home language has a negative correlation with science academic achievement in cases where only the language of instruction is used for all instructional purposes (McKinney & Tyler 2019; Monteagudo & Muniain 2019; Song 2019). Such students are expected to learn academic knowledge and skills through a decontextualised school science language which they have often not yet fully mastered.

In this regard, having deficient proficiency in the instructional language can become a noticeable hindrance to perform well in e-learning science education (Hua et al. 2020). This can, however, be emended if educators acknowledge and incorporate students' entire linguistic repertoire through multilingual pedagogy in e-learning (Iversen 2020). A recent body of research suggests that a heteroglossia orientation to education has gained momentum in global, fluid and mobile communicative spaces, as it promotes multilingual students' academic achievement in the science classroom through enhanced literacy (Allo 2020; Jang 2020; Olivares-Orellana 2020; Vallejo & Dooly 2020; Zhang et al. 2020) and this can also be incorporated into e-learning.

Recommendations

> 'Sir can't you just reteach us everything using our home languages?' (Sijabulile, male student, 23-years-old)

The *Language Policy for Higher Education* adopted by the government of South Africa in 2002 recommends multilingualism as a means to ensure equity of access and success in HE, in contrast to past colonial and apartheid education policies that left a legacy of inequality (Jang 2020), exclusion and a trail of continual failure (Krulatz & Iversen 2019). Multilingualism is a policy orientation towards the formal recognition of multiple languages and includes all the nonstandard varieties under postmodern notions of heteroglossia, which gives equal standing to all languages and dialects being spoken within a formalised system (García & Otheguy 2020).

Results from the present study and other recent research on multilingualism and multilingual pedagogy in e-learning offer evidence on the potentials of this pedagogy in improving students' academic achievement (e.g. see Charamba 2021a; Hua et al. 2020; Iversen 2020; Monteagudo & Muniain 2019; Olivares-Orellana 2020; Sangrà, Vlachopoulos & Cabrer 2012; Scott 2015). The present study, grounded in the conception that both students and educators bring diverse linguistic knowledge that can effectively be used as an instructional resource (Charamba 2021a; De Costa 2019), recommends the adoption of multilingual pedagogy in e-learning. In this way, not only will educators transform HE, but they will be doing social justice to the students as codified in the country's legislative frameworks. The approach also offers students much-needed support away from the traditional classroom. The study therefore recommends the use of heteroglossic pedagogies in e-learning of science.

Conclusion

The participants' interview responses suggest that multilingual pedagogy in e-learning presents both cognitive and sociocultural advantages: on the one hand, it maximises a deeper understanding of concepts and develops skills in the weaker language by rebalancing the power relations between languages (Vogel & García 2017). On the other, it supports home-university cooperation by enabling parental intervention in their learners' education. The study also demonstrated that the use of African languages in e-learning in today's HE promotes the interdependence of multilayered language systems by the simultaneous use of multiple languages within the same lesson.

To mitigate the possible negative academic effects resultant from students' low proficiency in the language of instruction used for e-learning, multilingual pedagogy is suggested where the students' linguistic repertoire is acknowledged and accommodated. This approach, based on the responses from the students and their performance in the assessment task suggests that one language does not exist in isolation from the other and typifies the '*ubuntuness*' of languages, a notion from the African epistemological orientation of complex continuity found in the injunction: '*I am because you are; you are because we are*' (Madiba 2014).

Chapter 16

Evidence of using digital stories as a pedagogy for isiXhosa second additional language learning

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Abstract

This chapter reports on how digital stories were used as a tool to teach isiXhosa second additional language (SAL). IsiXhosa SAL is an African language taught to preservice teachers who are non-isiXhosa speakers at a South African university in the province of the Western Cape. Guided by the theory of basic interpersonal communication skills (BICS) and cognitive academic language proficiency (CALP), the chapter pays attention to the process of additional language learning through the use of digital stories. The BICS and CALP theories recognise the strong bond between the mother tongue and the learning of an additional language. Data included lesson observation, unstructured interviews with group leaders and video analysis. The study reveals that digital stories have benefits for language learning and

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teaching (L&T), in both pre- and in-service teacher development. Digital stories can be explored in other learning areas as well as in teacher education during the post-COVID-19 era for the creation of digital teaching resources.

Introduction

This chapter reports on the use of photo story software to create digital stories; they are a digital tool used to teach isiXhosa as a SAL to non-native speakers in initial teacher education (ITE). IsiXhosa is one of the previously marginalised indigenous languages of South Africa and is currently an official language. Since the democratic elections of 1994, South Africa is still grappling with issues of social integration. However, Teacher Educators have a major role to play in addressing the gap of diversity through transformative, inclusive and collaborative pedagogical practices.

The teaching methods take place when the integration of information and communication technologies (ICTs) is viewed to have opened so many doors in the domain of education. The latter was witnessed during the time of the COVID-19 pandemic, particularly for learning, teaching and assessment during the lockdown in many countries. In the context of this chapter, the focus is on language education and the use of digital storytelling as a tool, as part of learning technologies.

According to Aboo Bakar (2019), storytelling is the oldest form of teaching about things such as history, culture and moral values. In the African context, storytelling used to be associated with grandparents, mostly grandmothers; they told fairy tales that taught children about the social aspects of life and moral values. In the olden tradition, some of the stories were created by the storytellers, using their imagination according to the things surrounding them, as there were no books to read and influence their thinking.

Therefore, in this contemporary digital age, language teachers and practitioners have an opportunity to explore the use of digital storytelling as a learning, teaching and assessment tool for ICT pedagogical integration. Similarly, the pedagogical use of digital stories could address the plight faced by teachers; namely that they do not know how to apply the 21st-century ways of teaching through technology. Therefore, the pedagogical use of digital stories is one of the communicative approaches to language learning, teaching and assessment. For Aboo Bakar (2019), digital storytelling is the brainchild of Diana Atchley, Joe Lambert, Nina Mullen and the Center for Digital Storytelling at the University of California, developed at Berkley in 1993. See also Lambert (2003) and Robin (2008). I used digital stories to teach isiXhosa SAL in the BEd Foundation Phase Teaching module, when the programme started in 2016.

Therefore, in the context of this action research, digital stories were used as a strategy to integrate the teaching of multilingual content for the majority of English and Afrikaans bilingual preservice teachers. Language and cultural diversity among the preservice teachers create new identities at a global, regional, national and local level. The statement is supported by a range of studies (Dabbagh et al. 2016; Mahieu & Joye 2018; Skutnabb-Kangas 2000, 2002; Stroud & Kerfoot 2013; UNESCO 2016). They highlight that linguistic diversity is a global phenomenon and that there are learning technologies that could be explored in pedagogical spaces.

The new digital and linguistic identities in this chapter pertain to the learning of isiXhosa SAL (a third language) under the Language Education Department in ITE. The new identities were explored through the lens of the BEd degree Foundation Phase I/c programme at the University of the Western Cape (UWC). This programme was part of the European Union project which aimed at strengthening the use of African languages in Foundation Phase (FP) Teaching in South Africa. The DoHET headed the project between 2011 and 2016 (Desai & Nomlomo 2014), and the recognition of African languages is continuing to be realised in academic spaces. According to Desai and Nomlomo (2014:90), teacher education is a complex activity that integrates different kinds of knowledge, in different contexts; thus this can create different identities for preservice teachers when they complete their degrees.

Therefore, the focus of this chapter is based on the initiative that I took as a teacher educator, to teach isiXhosa SAL. As mentioned earlier on, the module is part of the BEd FP teaching degree and is taught at first-year level. The name of the module is isiXhosa SAL, and the code is SXL101. This module is equal to the Afrikaans module code, SAL101 and both modules are compulsory for all the BEd Foundation Phase preservice teachers. Both modules equip the preservice teachers with communication skills that are required when they qualify as FP teachers, in order to go and teach in diverse communities of South Africa. However, the focus in this chapter is on SXL101, because SAL101 is an Afrikaans SAL module; it is compulsory for the nonspeakers of Afrikaans who have an African language as their mother tongue. Both modules are at Level 5 of the NQF with a NQF Credit Value of 10; they are offered throughout the year (University of the Western Cape Calendar 2019).

Problem statement

The preservice teachers come from diverse linguistic and cultural backgrounds with different cultural understandings and linguistic repertoires.

As a teacher educator, I have experienced the challenge of discovering how to teach isiXhosa to the preservice teachers in a meaningful way. I realised that because the preservice teachers were first-year students, being introduced to a new language, it was going to be a struggle when it came to the section of learning isiXhosa for meaning-making. Other parts of the module had been successfully covered, such as being able to make the click sounds of the target language, giving greetings and understanding the prefixes and suffixes in isiXhosa. This is in line with learning the vocabulary of the isiXhosa language. However, it does not make sense to an adult to memorise a language without being able to make meaning or create a meaningful sentence. Having seen that this was not going to be achievable, I explored the benefits of digital stories in enhancing the development of four language learning skills, namely, listening, speaking, reading and writing.

The choice of using the digital stories tool for language acquisition is supported by Ohler (2013) and Raymond (2008), who state that it is an e-tool that is project-based, where students are able to co-create electronic personal narratives using multimedia. I made use of a Grade R story to assess if the students were able to comprehend the story in isiXhosa; it was the same story that they had previously read in their mother tongue of English and Afrikaans. I grouped them into groups of three, and I achieved the learning outcomes of reading for meaning-making when I integrated the digital stories with the Grade R stories. The rationale behind resorting to digital stories as a teaching tool was that it was going to be carried out as an online project, and it was going to save us time. Secondly, the preservice teachers were going to share the tasks as they were going to create their own stories using the Grade R prescribed themes/topics.

Heo, (2009) and Merjovaara, Nousiainen, Turja, & Isotalo (2020)refer to digital stories as a powerful tool that connects young learners, from emergent to independent and fluent readers. In the context of this chapter, the preservice teachers are not young children, but they are adults that had already been exposed to the language and were in the process of making meaning in isiXhosa. The research question aims to address the research problem discussed.

Research question

What is the evidence of using digital stories as a pedagogy for meaning-making in isiXhosa SAL?

Significance of the study

Language Education is a field that is important in bringing about unity and addressing diversity and multilingualism around the world. However, the exploration of the use of digital stories will yield an understanding of the benefits of using technology in language L&T and assessment.

Literature review

United Nations Educational, Scientific and Cultural Organization advocates that language is a tool that promotes inter-cultural education and peaceful co-existence among communities (UNESCO 2016:9). Similarly, the success of using digital stories in teacher education, as outlined by Moodley and Aronstam (2016), supports a curriculum that integrates ICT.

Similarly, the use of digital stories as a multimedia tool is supported the following research studies: Bull & Kajder 2017; Chabinga 2015; Chambers 2010; Hatlevik et al. 2015; Gudmundsdottir 2010; Levy and Stockwell 2006; Malone 2014; Moodley and Aronstam 2016; Ou-Yang and Wu 2017; Raymond 2008; Robin 2008; Shandu 2011; Tiba, Condy, Chigona, Tunjera. 2015; Tunç 2017; Voogt, Erstad, Dede, Mishra . 2013; Yang and Wu 2012. The findings of the studies conducted by these researchers show that lessons that have been conducted with ICT integration have positive learning outcomes. In their research, they include lessons with and without the pedagogical integration of ICT. Information and communication technology integration for L&T has shown evidence of promoting learner-centredness, interactive learning, enquiry-based learning etc. as these form part of transformative teaching. All of these features are found in the creation of digital stories.

Globally and locally, HE, and teacher education in particular, is under pressure to provide a technologically responsive pedagogy. Similarly, researchers in HE such as Bozalek and Boughey 2012; Fraser 2009; ed. Kilfoil 2015; Leibowitz 2012; Soudien 2012), believe that in South Africa in particular, the landscape of HE is sandwiched between the policies of the past that favoured the hegemony of one or two languages; this has brought about inequalities up until today. Secondly, the pedagogical use of technology used to favour subjects like Mathematics and Science and was not applied in language L&T.

In the context of this chapter, the undemocratic policies include institutional language policies that are not akin to the promotion of multilingualism and multiculturalism with ICT integration. Information and communication technology in Education researchers suggest that preservice teachers should acquire digital literacy skills for transformative learning in order to gain pedagogical creativity and find meaning in their learning process (ed. Kilfoil 2015; Ng'ambi, Bozalek & Gachago 2013). In other words, preservice teachers should not only understand digital literacies, but they should practise an integrated way of teaching with ICTs in communities with diverse environmental, cultural, economic, historical and social factors when they qualify as full-fledged teachers (Ferns, Campbell, Zagwaard,2012).

Preservice teachers should be given an opportunity to design activities using digital stories, because such activities automatically afford an opportunity for the application of integrated language skills. For example, with the use of digital stories, preservice teachers will be able to draw from what they have learned in the development of listening and speaking skills in isiXhosa. The creation of digital stories will enable them to integrate listening, speaking, reading and writing skills. The book of Hardman et al. (2018) on ICT integration, explored the use of digital stories for language L&T in the South African context.

Digital stories as a learning and teaching tool

In the contemporary global information economy and in relation to the modern ways of learning, digital stories could be regarded as one of the valuable modes for the development of the four language learning skills. For example, the creation of digital stories with any kind of software, caters for the skills of listening, speaking, reading and writing. Aboo Bakar (2019), Robin (2008), Yang et al. (2012) state that digital stories have unprecedented benefits for students and learners as they promote interactive learning, particularly in language acquisition.

The creation of digital stories has its own processes that are similar to each other, depending on the envisaged end product of the project and its intended objectives. The objectives could be that of L&T, or assessment of what was learned, or the creation of a movie. For example, the study by Tunç (2017) outlined the creation of digital narration materials for teaching by students at the Anatolian Fine Arts High School in Turkey. The process of the creation of the digital stories included: 'a. the creation of an original script b. storyboard c. design characters d. background composition e. sound editing f. fictionalise with suitable software g. have the competence to use technology'.

Similarly, in a book by Ohler (2007), teacher educators are encouraged to explore this phenomenon, as a new pedagogical tool in order to enhance and expand their teaching repertoire and practices. The expansion of teaching repertoires is also supported by Beard (2001) and Robin, (2008) namely that teaching with digital stories affords teacher educators an opportunity to apply a variety of teaching strategies, such as group work, to promote interactive learning. They suggest further research should be conducted on the use of digital stories because of the impact it has on both preservice teachers and teacher educators.

While digital stories provide flexible learning benefits and opportunities (ed. Kilfoil 2015), the study by Tiba et al. (2015), shows serious concern about the fact that preservice teachers are determined not to use digital stories when they become teachers. According to Tiba et al. (2015), South African preservice teachers are not confident as to whether they would be able to use digital stories effectively; this is because of lack of resources and the curriculum that is restricted for ICT integration in schools. In line with this concern, the *White Paper for Post-School Education and Training* states that there is a need for HE to provide equitable access of ICTs' infrastructure to teacher educators (ed. Kilfoil 2015) This will, in turn, empower preservice teachers to apply flexible modes in curriculum delivery. Digital stories were used in a study to improve literacy skills; they proved to be an effective learning tool for students (Beard 2001). Similarly, in the studies by (Bull & Kajder 2017; Moodley & Aronstam 2016), digital stories were used in order to make use of interactive communication technologies as a form of multimedia. This was carried out in relation to students who were struggling in reading; the FP preservice teachers created reading lessons in early literacy. The findings in their studies suggest that digital stories placed technology in the hands of the students and provided them with a multidimensional learning experience while the learning objectives were achieved. In addition, the study by (Moodley et al. 2016) raises concerns around equitable epistemological access to ICTs as digital stories have shown to have pedagogical benefits in the development of reading and literacy skills. The development of reading and literacy skills through technology, is also highlighted in the findings of the study of (Yang & Wu 2012) for the learning of English as a foreign language. Digital stories helped in increasing the students' understanding of course content and increased their motivation and willingness to explore the process of learning English. According to (Yang et al. 2012), the English foreign language students' academic achievement, through the use of digital stories, has prepared them for further exploration of 21st-century technological advances. Therefore, in this chapter, digital stories are evidence of the development of 21st-century technological innovations as well as an alternative approach to additional language acquisition. The next section focuses on the theoretical framework that supports the L&T of additional languages.

Theoretical framework

On the premise that this chapter is about the learning of an additional language, I have adopted the theory of BICS and CALP in order to answer the research question. It is understandable that in most cases, these theories are used in the early literacy development of young children. However, in the context of this chapter, I find it relevant in the sense that it explains the process of language acquisition by preservice teachers in isiXhosa as a target language. In this chapter, it will be demonstrated that BICS and CALP work in a parallel fashion. The preservice teachers, who are adults, already possess a certain linguistic identity. They have been socially introduced to their mother tongue and other languages from birth. However, when it comes to isiXhosa, which is a degree requirement, digital stories are used to scaffold their cognitive use of language learning skills. In this case, isiXhosa acquisition is for academic purposes

Cummins developed a model called the 'linguistic interdependence model' (Cummins 1979, Cummins, 2008a; Phatudi 2015), where it is stated that there is a relationship between the mother tongue and the learning of additional languages. Language in Education researchers and practitioners such as (Skutnabb-Kangas 2001), refer to Cummins regarding their research on language acquisition by young migrant learners.

In the context of this chapter, the focus is not on young children but on early childhood education teachers, known as FP preservice teachers. The majority of preservice teachers are South Africans; they learn one of the previously marginalised languages as a degree requirement. Cummins' 'linguistic interdependence model' that is drawn from BICS and CALP, explains how preservice teachers learned isiXhosa SAL through the use of digital stories. Cummins describes an underlying cognitive or academic proficiency that is called Common Underlying Proficiency (CUP) and Separate Underlying Proficiency (SUP). The CUP and SUP are a cross-section between the mother tongue of the preservice teachers (English, Afrikaans and other languages) and isiXhosa. The BICS and CALP linguistic interdependence model, shares common features with digital stories, in relation to collaborative learning, critical literacy, active learning and building on the preservice teacher's prior knowledge (Cummins 2008a, 2008b). For this reason, digital stories may be a relevant pedagogic tool in language education as evidenced in the data analysis and the findings of the chapter.

Research design

Methodology

This chapter adopted the interpretivist qualitative research paradigm in order to reflect and interpret the pedagogical strategy and practices that I used in the process of SXL101 L&T, using digital stories. This research design was selected because it gives justification and illustrates the reliability of my data interpretation. In July 2021, at a workshop webinar on writing the methodology section, Prof J. Makonye, Dr N.S. Ndlovu and Dr M. Prozensky emphasised the importance of justifying the selection of a particular research design in conducting research. According to (Elliott 1991), the educational outcomes of action research are viewed in terms of student learning. In the context of this study, I used preservice teachers to learn isiXhosa during the process of action research. Elliott (1991:14) goes further as he considers teaching to be a form of educational research. He argues that separating research from teaching would imply separation between teaching and the curriculum. Therefore, the creation of digital stories by preservice teachers enabled and enhanced the pedagogical process for additional language learning and acquisition.

Method of data-collection

Thirty-one groups comprised of 93 FP preservice teachers participated in the action research module. Preservice teachers were divided into groups of not more than three. Using the alphabet, each group was given a name from *A to EE*. Each group was required to select a group leader who was going to interact with me as their teacher educator on a regular basis about the progress and challenges experienced by group members in the creation of the digital stories. The content for the creation of the digital stories was taken from the Grade R story themes/topics, available in all three languages spoken in the Western Cape province, South Africa, namely Afrikaans, English and isiXhosa.

I gave them an activity of creating digital stories; it required each group to choose a theme they would use to create a story that was different from the one in the Grade R book. I thus gathered data in the form of field notes on how preservice teachers created the digital stories, starting from choosing the theme, discussing the script, the planning of the storyboards, the creation and the selection of images.

The process of achieving the learning outcomes with technology was through digital narration. The groups were expected to create and tell a story around a theme of their choice. Creating and telling a story and using multimedia to record voice narration, the correspondence of a story being told with the digital images, sound effects of the story etc., would suggest that the group have managed to integrate technology into a digital story video for meaning-making. Before they started creating the digital stories, I showed them a video in order to view the process on their own and construct their own meaning. The video showed how Grade 3 learners created digital stories at Oakhill school in Australia, produced and created by Ms Denise and Allina Padilla-Miller.[15] This activity took place in a developed country and at an affluent school; it motivated the preservice teachers, as they had a vision and clue as to how their digital stories video would look as the final product. The main focus of this action research module was on the students' learning process of Grade R stories and prescribed themes/topics, from their own mother tongue (English and Afrikaans) to isiXhosa.

The stories were accessed by the preservice teachers on the Ikamva portal as part of the Centre for Innovative Education and Communication Technologies (CIECT) at UWC. The training process that was offered by the CIECT included the preservice teachers and me. I joined the training because I was also a novice in the technical issues regarding the tools that are used for the integration of technology for language L&T. Every type of communication with the entire group of preservice teachers in relation to the project was sent via the UWC Ikamva website. This ensured that almost every student was accommodated in the digital story creation process. In addition, all the Grade R stories, prescribed themes/topics, learning and support material (LTSM) and assessment rubrics were sent on this platform.

The preservice teachers created a story from a theme; this took place in their own space where they were able to access the Internet, which is provided on campus for access to technology. Gudmundsdottir (2009) says that access

15. See https://www.youtube.com/watch?v=rUZXBc6yRhU

to ICTs is influenced by various access factors such as material access, which refers to Internet resources and the infrastructure. The mental access refers to how ready the millennial FP preservice teachers were to integrate ICTs into their learning process, emotionally, socially, cognitively, culturally and contextually. The skills access and usage access refer to the use of digital skills for teaching and learning in the FP classrooms when the teachers complete their degrees.

Data-collection was carried out through classroom observations during f2f group interactions. I also conducted unstructured, informal interviews with group leaders as they facilitated the process of digital stories creation. I recorded the process of each group by writing down their concerns, challenges and complaints about those students who were not fully participating in group work activities.

Data analysis

During data analysis I coded data and created themes according to what I had observed in the f2f groups and heard in the audios of the group leaders. Using content analysis, I watched the videos and analysed them. The discussion and the findings of the study are in the next section.

Presentation and discussion of the results

The results of the chapter highlight that there is evidence that shows that digital stories can be used to learn and teach additional languages. This section entails the discussion of the results for various themes that emerged from the classroom observation, or from unstructured or informal interviews that I had with the group leaders.

Development of translation and pronunciation skills

During the time that I was teaching the module, the data from the classroom observation and the interview with the group leaders yielded the same results. For example, I observed that during the SXL101 period, the preservice teachers used to communicate with each other in their home languages. During lectures, we were in a traditional classroom with no digital resources, as illustrated in Figure 16.1:

Similarly, one of the Afrikaans home language group leaders attested that they made the shift from being in their comfort zone of communicating in Afrikaans home language to English as a First Additional Language (FAL) and to isiXhosa SAL. The extracts illustrate how the group navigated the process of moving out of their comfort zone. The comfort zone was one where they were using their listening, speaking, reading and writing skills in their mother

Source: Photograph taken by Nonhlanhla Shandu-Omukunyi, exact date and location unspecified. Published with appropriate permission granted by Nonhlanhla Shandu-Omukunyi.

FIGURE 16.1: University traditional classroom.

tongue, whereas this time they had to reach the level of third language acquisition:

> 'Before we got it right, our group translated the story from Afrikaans to English first, in order for all of us to understand and make sense of the story.' (Participant 1, female, FP preservice and the group leader).

We chose the Grade R theme, 'People who help us'. Our Xhosa topic was '*Silahlekelwe yibhokhwe yethu uGeorge*' which means, 'We have lost our goat, George' (Group Leader) (Adapted from a DIGITAL STORIES video created by a group of preservice teachers).

The video was created by the students while they were doing the module. They gave me permission to make use of it, as well as the CIECT Director, Dr Juliet Stoltenkamp.

The preservice teachers' creation of the digital story video using digital pictures for narration made the story interesting as it literally shows how different people helped them in a quest to find the lost goat, George. In short, the digital story video starts as they were asking people about the goat that was lost. For example, in the digital story video, when they were looking for the goat they asked a nurse. The participants have translated the word nurse in isiXhosa as '*umongikazi*', the postman as '*unoposi*', the firefighter as '*isicimi mlilo*' and the teacher as '*umfundisi ntsapho*'. The isiXhosa pronunciation of words in the video indicates that the preservice teachers had already developed certain skills in the target language. However, the development of the digital story video allowed the group to use translated words and the pronunciation of isiXhosa clicks with the narration in a meaningful way.

This suggests that there is value to be found in digital mental access as suggested (Gudmundsdottir 2010). This brings confidence to preservice teachers in cocreating the DIGITAL STORIES video from the perspective of linguistic interdependence (Cummins 1979; Phatudi 2015; Ukpokodu 2004). The mother tongue or home language of the preservice teachers and the process of digital story creation influenced their confidence in being able to create a story within a story through storytelling.

In this case, it seems that the development of translation and the pronunciation skills in the preservice teacher's sentence construction, is noteworthy. Also important is the fact that the entire digital story video is evidence-based; not only for assessment but for the preservice teachers to add their work to their e-portfolio to showcase the skills they possess when they seek employment. In addition, the evidence-based digital story video confirms that the learning objectives of the video have been achieved. Lastly, the preservice teachers have developed confidence and can brag to their fellow isiXhosa speaking friends and classmates.

Multimedia for linguistic interdependence

In the process of learning an additional language, the participants engaged in a difficult task, namely the use of clicking words through isiXhosa phonic awareness and understanding the syntax.

In the video recording of the digital stories, three group participant members took turns in narrating the story about 'Okufundwe nguAvela esikolweni'. In English, it means, 'What Avela learned at school'. The theme of the original story was 'Shapes and colours in my environment'. In isiXhosa it says, '*Izimo nemibala kwindawo endihlala kuyo*'. The respondent said:

> 'We first discussed the what, who, when, where and the how [...] We chose our characters, background music, props we were going to use and *colours* that go with our story.' (Group O Leader, age unspecified, date unspecified)

The reference to the mentioned theme is quite relevant to what Cummins calls CUP and SUP when balancing BICS and CALP theory, within the linguistic interdependence model (Cummins 1979; Phatudi 2015). For example, this finding speaks to the literature that supports the interdependence of concepts, skills and linguistic knowledge of shapes and colours in any target language. The preservice teachers were able to use the CUP by applying innovative thinking in order to conceptualise the idea and construct their own knowledge using prior knowledge about colours. The application of the digital story played the role of bringing together the CUP and SUP for meaning-making. Therefore, the role played by different characters, background music, props and colours brought life to the new story and to language acquisition by the participants. So, the use of multimedia afforded the preservice teachers an opportunity to put together the fragmented resources in order to make meaning. When they put together the characters, music, props and colours, the aim was to create a final digital product that sends out a children's story, to be used in future as a FP digital resource. Technology integration afforded the preservice teachers an opportunity to develop from lower to higher-order thinking skills, as they were creating a new story from a Grade R book theme. In other words, the lesson objective of constructing simple sentences on their own for meaning-making in isiXhosa, was achieved. Additional language learning requires repetition as stated by Phatudi (2015) with regards to the methodologies to teach English FAL. The interactive approach during learning, with ICTs integration, is supported by (Shuker & Terreni 2013), where students independently selected their own multimedia material like, pictures, music and graphics (Tunç 2017) to enhance the learners' story-making and make it fun, interesting and educational.

Conclusion

In conclusion, the study clearly shows that there is a link between additional language learning and acquisition through the use of digital stories as a L&T tool. As it has been proven by research that ICT integration is a complex phenomenon, this study shows that digital storytelling is the solution to another complex phenomenon of linguistic interdependence. What I observed during the time of teaching the SXL101 module, the responses I received from the group leaders, up to the process of digital story video creation by preservice teachers, is clear evidence for the adoption of digital stories by Teacher Educators at South African universities.

The study also highlights that Language Teacher Educators should find ways of nuancing digital storytelling as a tool to apply flexible learning during the challenging global times of the COVID-19 pandemic. In the chapter, I discussed the benefits of multimedia in developing the thinking skills of the preservice teachers, from lower to higher-order. The latter suggests that there is potential for preservice teachers to apply these skills when they join the teaching profession. Therefore, the use of digital stories as a pedagogic strategy could also inform policy decision-makers in both Higher and Basic Education.

In view of the findings, this action research study recommends the following as a means of encouraging teacher educators to consider using digital stories as a tool for L&T.

Given that the learning of additional languages is a multilingual and multicultural challenge, the use of digital stories as a L&T and assessment tool should be prioritised. This should apply across the curriculum and not only in language education for socio-culturally embedded pedagogies. In addition, the use of digital stories will help in preparing the preservice teachers to be ready to teach additional languages in South Africa and beyond.

Digital storytelling shows to have more benefits than barriers to L&T. It is project-based and allows collaborative learning through the use of diverse digital resources and the co-creation of knowledge. It is multifaceted and could be used across the language learning curriculum and other learning areas such as science, humanities and commerce. The findings of this action research study show that the use of digital stories as a learning, teaching and assessment tool, is unprecedented. The benefits of mediated learning and innovation requires preservice teachers to be given support through ongoing teacher development at HEIs.

Chapter 17

The many voices of the 'digital turn': Four lines of inquiry into education and the digital in post-COVID-19 South Africa

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Abstract

The 'digital turn' in education is usually spoken of in the singular, but the intensifying relationship between digital technology and education is practised and theorised in multiple and often conflicting ways. Based on a synthesis of the preceding 16 chapters of this volume, exploring how they relate to and inform each other as they investigate the central question of the book – *how are ICTs transforming transform teaching and learning, and teaching education?* – my argument uses the dynamic tensions of the chapters' many voices as an invitation to trace new ways of problematising the role of digital technology in education, for South African teachers and teacher educators, and new ways to be responsible to these problems. I trace four lines of inquiry, guided broadly by concerns with teaching and knowledge, care, political critique and affect, and end by looking

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beyond the current volume's focus on digital technology in formal education to suggest further investigations into the networked publics that young South Africans are engaging in and the possibilities and challenges offered to education by the informal learning occurring in these spaces.

Introduction

'How can the use of digital technology transform teaching and learning in general and teacher education in particular?' This is the question that the chapters of this collection address from a range of perspectives and South African contexts. The title of the collection calls these responses *case studies* because most of them engage with the practicalities of teaching with information and communications technologies (ICTs) in specific, bounded contexts, but they are also personal testimonies, reflections, historical traces of the coronavirus disease of 2019 (COVID-19) pandemic moment as lived by their authors. They aim to make sense of the unprecedented intensification in the relationship between education and the digital that was brought about by the lockdowns and school closures mandated in communities all over the world during the COVID-19 pandemic, drawing on experiences both before and during emergency remote teaching (ERT).

This chapter offers an explicit synthesis of the 16 chapters of the volume, exploring how they relate to and inform each other as they contribute to the main theme of the book by drawing out four interlinking strands of argument relating to how the integration of digital technology into teaching and learning can be framed and the conceptual, practical and ethical consequences of these framings. The case studies presented in this volume demonstrate the heteroglossic nature of what is sometimes presented as a single 'digital turn' in education, as different theories about the nature of learning and pedagogy, the aim of education and the role of the teacher and the ethical and political scope of education, result in widely differing interpretations of what successful integration of digital technology would look like and how to train teachers to achieve it. The tensions between these differing projects, with the different experiences and contexts they recount and the different theoretical assumptions underpinning them, should not be smoothed away – rather, they invite attention as moments that reveal new ways of problematising our shared question of *how ICTs are transforming and can transform teaching and learning and teaching education*, and new ways to be responsible to these problems (Springgay & Truman 2018:207).

Moll, in the opening chapter of the book, argues that the competing learning theories of behaviourism, cognitivism, constructionism, socioculturalism and embodied cognition, are best understood and taught as 'moments in the historical progression of ideas about learning', the 'accumulation of explanatory hypotheses over time'. The chapters that follow show clearly that later theories do not wholly supplant their predecessors, resulting in a heterogenous tradition of discourses around what digital technology can contribute to education. The theory of knowledge and learning you work with, with its epistemological and ontological assumptions, shapes the pedagogical possibilities you see, what appears as problematic, and what frameworks you will call on to understand your situation. Two major schools of thought around e-learning are well enough established and sufficiently clear in their theoretical articulations to warrant clarifying before I move into discussing the individual chapters, because the chapters tend to align more closely to one or the other of these two opposing schools. Clarifying their general orientations will make my discussion that follows more succinct while retaining precision. At the risk of caricaturing these longstanding intellectual traditions, their broad outlines can be described as follows.

The first, which has been called technological determinism, is (Hinrichsen & Coombs 2014):

> [T]ypified by conceptions of technological neutrality (a tool paradigm, open to positive or negative uses), autonomous advancement (we must adapt 'because it is here'; the dangers of being 'left behind') or proselytising (universally positive impacts; polarising constructions such as 'dinosaurs' or 'luddites'). (n.p.)

This understanding tends to build on a conception of education as training the intellect, to equip students to move into roles in the global economy. This position implicitly builds on more cognitivist or strictly rational constructionist learning theories and frames desired learning outcomes in terms of autonomous cognitive skills which can be applied by every individual in all contexts. These '21st-century skills' are named as discrete cognitive abilities such as collaboration, teamwork, creativity, critical thinking (CT) and problem-solving. Learning in this model is primarily stocking up on skills, and the role of ICTs is often conceived of in terms of providing rich and flexible learning environments, where 'environment' applies to the physical classroom and extended digital spaces in which learners engage with learning materials. Extremely influential public documents such as the UNESCO Competence Framework draw on this tradition of understating the digital and its place in education.

The opposing approach, sometimes called social determinism, argues that no technology emerges outside the shaping effects of political, economic and sociocultural context and rather 'reflects these purposes, influences and meanings and thus is never neutral' (Hinrichsen & Coombs 2014). Such approaches are more rooted in critical theory and pedagogy and sociocultural literacy theories, which emphasise education as contextualised and aiming to produce people capable of informed ethical and political agency as members of their communities. Knowledge and knowing are understood as constructed and situated practices rather than autonomous skills. Learning in this model is a process of identity formation and change which happens in dialogue with others, both human and nonhuman.

Some shared roots in the history of contemporary Western educational theory has resulted in these two largely opposing schools of thought sharing some central terms, which thus have overdetermined and profoundly conflicting meanings which cannot transfer between the two sets of discourse and can thus cause confusion. This is the case with a central term from this volume's guiding question, which is *transformation*. In the UNESCO framework, this term applies to the 'application of digital skills' in education, at the highest level of competence, namely 'knowledge creation'. Existing knowledge is transformed into new forms, new modes and new markets. In contrast, transformation in critical education terminologies carries a distinctly political weight – as Aghardien in Chapter 2 puts it, critical education 'involves cultural work, [and] has social justice ideals, transformation and redress at its core'. Her use of another overdetermined term, 'critical', must also be read carefully. In a technological determinist framing, 'CT' means the type of cognition higher up on educational taxonomies such as Bloom's, whereas to the social determinist, it means a praxis-oriented critique of the relations of knowledge with power as these relations shape social injustice and inequality.

With these possible confusions clarified, I will move now into tracing the four directions of inquiry which I see emerging from the varied voices of this collection's 16 chapters. The first concerns the central role of the teacher as it exists in mainstream Western tradition, as a professional trained to recontextualise (Bernstein 2003) knowledge into specifically educational knowledge in particular subject disciplines. A great deal of careful work remains to be carried out in exploring the kinds of knowledge and knowing valued in the disciplines in explicit terms, so that creative pedagogies can develop that draw on the full range of affordances offered by digital technologies, rather than relying on very generalised notions such as 'anywhere, anytime learning', and these chapters make significant contributions in this area. A second line of inquiry, however, shows the richness of the teacher's role, which extends beyond a focus on knowledge to include pedagogical bonds centred on relationship and care as fundamental to successful education (Zembylas 2017:3). Several chapters address such concerns explicitly while several more, I will show, do not frame their findings using theories of relational pedagogy but nevertheless raise points that show the importance of dialogue, empathy and care as ethical concern, in understanding how ICTs should be integrated into education at both classroom and policy levels. The third line of inquiry takes this trajectory to explicitly political questions about power, access and equity in digital education, tracing complexities of exclusion and invisibility because of institutional power and language. The final thread, which I trace as the least clearly developed in the preceding 16 chapters, and therefore perhaps with the most potential for innovative research, is a focus on affect. Zembylas (2021:1) argues that the recent 'affective turn' in education theory 'creates important ethical, political, and pedagogical openings in educators' efforts to make transformative interventions in educational spaces'. Digital devices are not simply tools for teaching but simultaneously objects of desire, causes of anxiety, carriers of powerful ideological discourses around digital technology and 'smart' devices as markers of modernity and development that situate Africa and Africans in complex ways that often reinforce existing inequalities and redouble historical traumas.

Teaching, knowledge and digital affordances

One way to understand what teachers do with knowledge is via Shulman's (1987:8) concept of pedagogical content knowledge (PCK), 'that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding'. For Shulman, PCK is made up of two core parts (Berry, Depaepe & Van Driel 2016):

> [*K*]nowledge of useful forms of representing and formulating specific subject matter (e.g., through schemes and analogies), and knowledge of students' conceptions, misconceptions and learning difficulties regarding that same subject matter. (p. 347)

Mishra and Koehler (2006) adapted Shulman's original model by adding the category of technology alongside content and pedagogy, to generate the additional areas of technological content knowledge, technological pedagogical knowledge and finally, technological pedagogical content knowledge (TPACK) framework, but the fundamental logic of trained thinking about thinking remains the same as in PCK. Building up stores of these core knowledges is a lifelong process involving the teacher's openness, attention and presence to the community of learners in the classroom but begins with identifying the ways of thinking, knowing, reading and writing which are valued in the teacher's specific discipline. A cluster of studies in this volume begin their engagement with how ICT can be integrated into teaching by working to bring to explicit statement the subject-specific thinking skills the authors need to teach, as educators training future teachers in these teaching subjects. Adelabu et al. in Chapter 10 focus on a particular cognitive process valued in Mathematics, which is breaking down a geometry problem into its constitutive parts, while Khoza in Chapter 14 discusses a complex visualisation practice, known as 'spatial skills', which students of Engineering Graphics and Design (EGD) need to do sectional drawings of the interiors of 3D objects. Selecting and implementing appropriate software packages for supporting these skills, as these two chapters show, rely on bringing these mostly unconscious mental processes to visibility.

Makonye in Chapter 9 also works in the field of Mathematics and, drawing on a constructivist understanding of learning, argues that to use mathematical software such as GeoGebra optimally a teacher's range of knowledges much include not only TPACK but also diagnostic knowledge. In other words, once the specific thinking skills required for specific mathematical fields are clearly conceptualised, the teacher can identify exactly where students are going wrong and then design or select tasks that scaffold the specific mental operations that are proving difficult. The affordances of apps such as GeoGebra, which allow teacher and students to rapidly and easily work together across semiotic modes used in the representations of mathematical concepts (verbal, visual, numeric, algebraic, graphical or abstract), broaden the possibilities of making thinking visible, for supporting learning.

Two other chapters also explore the importance of making thinking visible but this time focusing on what Shulman calls general PK. Phakathi and Moll in Chapter 6 draw on the notion of thinking routines, which are 'simple, specified or "signposted" pattern[s] of thinking' that correspond to cognitive skills valued across subject disciplines, such as perspective-taking or supporting a point with evidence. Teachers can model these routines explicitly and repeatedly, so that learners become familiar with them and practise them (Ritchart & Perkins 2008). Using ethnography, Phakhati and Moll explore the representational affordances of iPads with their apps for making these routines visible, as practised by both learners and teachers, in a Grade 7 class. The precision with which they appraise the iPad's affordances, from its size and portability through to the specific apps integrated into its operating system, depends on the rigour with which the desired thinking patterns are specified. They also sound a cautionary note, in a reminder that just as a device or platform's particular array of affordances *enables* particular kinds of learning, so too does it *constrain* others, which is a point I will develop further. Van der Westhuizen in Chapter 12 also uses thinking strategies, matched to Webb's depth of knowledge (DOK) levels, to design a series of scaffolded assessment tasks for preservice Chemistry teachers that helps them move from lower-order to the higher orders of evaluative and creative thinking on Bloom's taxonomy. Here the thinking is made visible to students by being incorporated into assessments, which are widely known to drive students' engagement and learning (Biggs 1996).

Chapter 7 by Van Wyk and Moodley considers the role of assessment even more explicitly, investigating the experiences of adult lecturing and learning and teaching (L&T) support staff at a large public university in South Africa who complete a 'computers and e-learning' course structured around a course-long authentic assessment design and taught in a blended mode. Guided by the constructionism learning theory, which 'places students in the role of designers and emphasizes creating tangible artefacts in a social environment', Van Wyk and Moodley put self-, peer- and facilitator assessment at the heart of their course design, and the staff attending the course are shown to develop not only higher-order thinking skills but also confidence and a sense of self-efficacy in using ICT tools in teaching. The aim was to prepare these adult learners for the authentic demands of their roles as teachers in the rapidly technologising HE sector; making this pedagogical aim explicit guided the course designers' choice of ICT, pedagogy and assessment design. In the end their study demonstrates both core elements of PCK – knowledge of the ICT they teach about and of the needs of their students – although they do not explicitly invoke Shulman's concept.

Modelling, explicating and assessing knowledge and thinking skills is only part of a teacher's role, however. To be fully intentional about the digital turn under COVID-19 pandemic conditions, the close focus on specific cognitive skills which characterises the chapters I have discussed must be complemented with problematising that considers the role of education as equipping students with capacities for care, relation, dialogue and political agency.

Teaching, care and agency

The technologisation of education, as Guilherme says, puts a double pressure on teachers and on teacher education. They now have to develop their learners' ICT skills in the context of powerful global discourses around the 'creativity and intellectual excellence' required for success within 'a globally technological and economically demanding society', while simultaneously developing their own (Guilherme 2019:48). Yet this emphasis on intellect and skills neglects the aspect of the teacher's role which many teachers cherish as more central to their sense of self, namely the task of developing the student's (Guilherme 2019):

> [*C*]apacity to be someone who is concerned for others in the community, who engages with the various problematic issues of society, and who is aware of the impact of actions upon himself or herself, others, and society as a whole. (p. 48)

Several chapters in the book engage with the intellectual and emotional strain of this unresolved tension, which was given a sense of existential urgency by the stress of ERT. Martin et al., in Chapter 5, characterise their experiences as teacher educators as essentially a completely disorienting sense of *change*, accompanied by the urgent pressure of needing to learn new knowledge and skills. Even before the COVID-19 pandemic, an increased role for digital technology in the classroom both decreased some aspects of the teacher's role and added new aspects. For example, teachers no longer need to be the main source of subject content, which can now be searched for online, while at the same time they need to be software trainers, as the chapters by Dewa (ch. 11) and Khoza (ch. 14) in this volume show. One response to these changes is to argue that teachers must rather be understood as facilitators or mediators of the learning process; Van Wyk and Moodley in this volume, for example, hold to this view. Yet others argue that what the teacher brings cannot simply be reduced to mediation. While certain aspects of PCK can be dispersed across new roles, such as online materials developer or platform designer, the role of teacher in being authoritative guide, model and partner in dialogue, the ethical and political dimensions of teaching, cannot be so easily replaced or displaced onto other roles. To theorise these aspects of teaching, a move beyond psychological theories of learning is needed, to ideas around pedagogies that centre relationships and care.

Ndlovu, in Chapter 13, provides a striking example of the role of human presence in teaching, whether online or f2f. She focuses on the specifics of using a LMS to teach a particular subject – digital literacy – to a large class of digitally inexperienced students wholly online, and she does find that her responsibility as lecturer shifts towards a greater focus on establishing clear structures and processes first and foremost, rather than subject content. She developed what she calls a 'cascading communication system' that grouped students into successively larger peer-, tutor- and then class-groups, as mechanisms through which students could receive (and provide) prompt answers to questions and feedback on confusions. However, the online community built in this way does not function to help students only to construct knowledge but also to care for each other. The voices of the students, which come out clearly in this chapter, emphasise how irreplaceable interpersonal contact is: one recounts how she would attend weekly online clarification sessions with the lecturer not because she needed to ask any questions, but because experiencing the lecturer's warm and reassuring manner online gave emotional support. Ndlovu discusses this aspect of her course using Garrison, Anderson and Archer's notion of social presence within an online CoI (Garrison 2009) that seeks to promote higher-order thinking. Community of inquiry is a sociocultural theory of learning as distributed cognition, which locates learning socially rather than in the individual. Martin et al. in Chapter 2, already mentioned, draw on a similar theory of learning, namely connectivism, to trace their own learning about TPACK. Arguably however, these learning theories give insight primarily into the instructional role of the teacher and not the personal role of making the students feel cared-for (Meyers 2009). The personal reflections of Martin and her fellow authors reveal that what troubled them most about the change to online learning was the ethical and political duty of the teacher to provide epistemological access to powerful forms of knowledge to students from outside this knowledge tradition. Their thinking about pedagogical reasoning and connectivist methods of learning together derive urgency and meaningfulness when set in a framework that extends beyond learning theories.

Na-Allah and Nkambule, in Chapter 4, explore the realm of policy and implementation and note the importance of dialogue and relation at this systemic level. Reporting on teachers' on-the-ground perceptions of how South African policy on the integration of ICTs in schools, they find that teachers feel they are not consulted when policies and implementation frameworks are drawn up, and this lack of dialogue between policy planners and teachers results in mutual ignorance and endemic failures in policy implementation. Linking back to the importance of matching ICT implementation to pedagogical thinking I discussed, Na-Allah and Nkambule show that teachers know they need such contextualised training but do not receive it in current TPD programmes. Aghardien, in Chapter 2, also focuses on TPD but at HE level. She draws on Archer's social realist theory of corporate agency to emphasise how in joining communities with collective identities, people as agents in building society develop capabilities, roles and identities that are more than the sum of the individuals making up these communities. She argues that TPD both about incorporating ICTs into teaching and teaching by means of ICTs must involve forming PLCs precisely because among the emergent properties of such a community are care and dialogue, which are prerequisites for transforming South African education towards social justice and redress.

These chapters carry the conversation around how to implement ICT towards the personal and simultaneously towards explicitly ethical and political considerations of the role of education. Together they give insight into the challenges brought about by changes of scale, contrasting the flexibility a single teacher can have, reflecting on and adapting her use of ICT as a course proceeds, with the weight and inertia of province-wide or country-wide implementation programmes. What is revealed is how the successful integration of ICTs into education systems is profoundly dependent on political structures, in the sense of whose opinions are sought and heard, whose realities taken into account and whose rendered invisible. To this third direction of inquiry I now turn.

Teaching, access and social justice

A major argument for integrating ICTs into education, on which many of the chapters in this volume draw, is the emancipatory potential of the technology in universalising access to education. Information and communication technology can be a tool, with a power never before known in human history, to give access to information and to networked publics. However, such arguments must avoid the danger of what Fraser calls 'misframing', which is misrepresenting the realities of who is included and who is not included in these claims to equity and empowerment (in Bozalek & Boughey 2020). Equity of access to ICTs and to their affordances and benefits is in fact denied to many people in South Africa as elsewhere, because of economic exclusion through poverty and cultural exclusion through the invisibility of nonhegemonic languages and cultures (Bozalek & Boughey 2020). Over-dependence on ICTs risks making them institutionalised obstacles that actually *prevent* parity of access to social goods – there is an emerging literature around *exclusion by design*, examining how increasing technologisation reinforces existing inequalities and creates new gaps (Park & Humphry 2019). Several chapters in the book suggest that teacher educators need to teach with, by and about ICTs in transformative ways, meaning ways that do not just 'correct inequities created by social arrangements' but which rather 'address the underlying root causes or underlying generative framework' of exclusion by design (Bozalek & Boughey 2020).

Na-Allah and Nkambule, as mentioned, expose how in policy processes in South Africa, teachers, particularly within the government school system, and their experiences and understanding of what they need in terms of training and support, are largely invisible. The study's findings point to a relationship that is almost 'causal' in strength, between consultation with and involvement of teachers and principals and the success of policy implementation on the ground. Policy documents such as the White Paper on e-Education (DBE 2004) are guilty of the misframing Fraser warns against, a powerful form of political exclusion. Hoosen, in Chapter 3, finds similar patterns in one of South Africa's large public universities, where lecturing staff report the tension between institutional policies and goals in terms of ICT integration on the one hand, premised on technicist competency frameworks, and on the other, the 'institution-wide limitation[s] around training, technical support, infrastructure, and time' experienced by teaching and support staff. Like Martin et al., Hoosen argues that one of the surprisingly basic needs in this post-COVID-19 moment is simply time – time for PD and learning, to allow lecturers to convert the greater *mastery* of the available platforms, apps and devices they developed during ERT into the greater *freedom and creativity* promised by technophilic discourses, including the undoubted potential of ICTs for the fuller emancipatory praxis of critical pedagogies. But the misframing, even erasure, of constraints in policy documents and teaching plans impedes this development.

Several other chapters address cultural exclusion, primarily via language. Charamba and Nyatsanza in Chapter 15 note how the question of language is often taken for granted in discussions of ICT in education and particularly notions of *anytime, anywhere learning* and *ubiquity of access*. They emphasise the embeddedness of ICTs in wider historical and colonial structures of power, arguing that the affordances of e-learning can only be truly estimated when accompanied by critical insight into the multiple digital divides that shape access. These divides include not only access to devices and software, and to electricity and Internet infrastructure but also to the languages used by apps and online communities. (They could have added to this list of inequitable structures the representational bias embedded in algorithms; Baker & Hawn 2021.) Charamba and Nyatsanza focus on how using English as an exclusive language of learning and teaching (LoLT) limits science students' epistemological access and their success in assessment. They demonstrate this using the simple expedient of translating the subtitles of asynchronous recorded lectures, and the multiple-choice assessment questions of a university Physics exam for preservice teachers, into two more of South Africa's official languages. The findings emphasise not only improvements in the students' learning of scientific concepts but also their sense of motivation and also increased status and visibility for African languages. An important distinction Charamba and Nyatsanza draw is between digital literacy, in the sense of knowing how to use ICTs, and information literacy, which is the ability to critically assess the embeddedness of online content in political structures of inequality, such as monolingual bias. They argue that part of information-literacy education, particularly for multilingual countries such as South Africa, must be 'language appropriate' technology-enabled teaching and learning environments.

In addition to multiple languages, Charamba and Nyatsanza also discuss how the use of ICTs for formal education exacerbates inequalities in students' access to different levels of discourse within the LoLT. Many multilingual students have good proficiency in everyday social English (BICS, in Cummins's formulation) but restricted knowledge of the English valued in academic disciplines (CALP). Charamba and Nyatsanza find that in f2f classes, students form unofficial communities of learning by using their other languages to explain difficult English terms (CALP level) to each other; an inclusive multilingual online pedagogy would have to provide opportunities for such strategies to be practised remotely. Khoza, in Chapter 14, also shows how students being trained to use ICT in the classroom often need instruction in their primary languages, rather than in the LoLT, for similar reasons of having better BICS than CALP in English.

Two other chapters add to this exploration of how complex are relationships between ICTs, pedagogy and multilingualism. Shandu-Omukunyi in Chapter 16 examined an isiXhosa additional language course for preservice teachers that was designed around a digital story assessment project. She finds that the course depended for its success on being embedded in classroom sessions that allowed learners to design their digital artefacts working together in their own primary languages, even though the final story had to be in isiXhosa. Here successful integration of ICTs depended not on technical support but thoughtful negotiation between the course's pedagogical aims and students' actual language repertoires. Along similar lines, Mlotshwa, Ndlovu and Nyandoro in Chapter 8 find that of all subject specialists in their large-scale study of ICT adoption among Gauteng teachers, African languages teachers show the lowest use of smart notebooks into their lesson preparation. This is not because of any technology-related factor, but rather because historical patterns of political oppression and underfunding have left African languages with the least well-developed body of teaching materials, particularly digital textbooks.

Certain powerful discourses around ICTs and access, and the expectations and assumptions they foster in education professionals of a straight route to universal improvements in education, are thus in tension with the endlessly varied contexts of actual implementation in politically and culturally complex societies. These tensions existed before the COVID-19 pandemic brought us all to ERT, but as more teachers went online than ever before, these tensions and their personal consequences, including emotional effects, became more visible. As the final line of inquiry, which is the most tenuous of the four I discuss here in its current state of development in the chapters of this volume, I draw together suggestive hints that have to do with what Zembylas (2021:1) calls the affective turn in education, which is theorising that 'draws attention to the entanglement of affects and emotions with everyday life in new ways'. This theorising reveals aspects of the intensifying relationship of education with the digital that the previous lines of inquiry informed by theories of knowing, caring and political critique leave hidden.

Teaching, affect and the digital

Emerging theories of affect in education (see Zembylas 2021 for an overview) embrace several meanings of the term 'affect'. The first is used in theories of learning in Psychology, as in Moll's discussion in chapter 1 of embodied cognition, to emphasise how emotion or feelings, rather than being nonrational, are deeply involved in processes of forming and internalising knowledge. The other occurs more diffusely across Sociology, Cultural Studies and Political Science, for example, and emphasises that emotions are 'culturally and socially constructed and performed based on social norms' (Zembylas 2021:3) and so produce and reproduce social structures, discourses and practices as well as responding to them (Zembylas 2021:5). In other words, the psychic is entangled with the social. Thinking about affect in this way helps to reflect on education in traumatic contexts, whether temporal such as the COVID-19 pandemic, or spatial such as the urban landscapes in which large public universities in Africa are situated, crisscrossed by chasms of social injustice, poverty and suffering.

Moments of affective intensity appear in several chapters in this volume. Martin et al. talk about the disorientation experienced by teacher educators, at profound levels of their self-understanding as teachers, caused by the move to ERT. Their chapter is motivated by a profound need to make sense of this disorientation, to make it productive not only in terms of improving their teaching with ICTs but also in coming to terms with the changes brought about in their sense of self. Martin et al. locate this self at a profound level, as 'the core of the university – our identities as scholars', suggesting the magnitude of the trauma they experienced under ERT. They describe their motivation for their chapter in active terms as a 'decision to focus on reconstituting [their] professional identity', encapsulating a task that all teachers face as ERT moves into a still unstable 'blended' future. The trauma of ERT also appears, from the point of view of both students and teacher, in Ndlovu's chapter about teaching the large introductory ICT literacy class online. The students' insecurities, fears and anxiety manifested in the only possible means of contact they had with their lecturer, which was in written text, via e-mails and WhatsApp, the strain of responding to which led Ndlovu, in the first iteration of the course, almost to a physical and emotional breakdown. This is a very clear example of affect inscribing itself on bodies. Her solution, the cascaded communication system described, could helpfully be understood as a mechanism for channelling the unruly affects unleashed by the COVID-19 pandemic conditions under which the students were working.

Other chapters talk more broadly about affect under the terminology of intrinsic or internal barriers to the adoption and implementation of ICTs in education. Khoza uses the TAM, which proposes that how an individual balances PEOU over against PU is instrumental in their deciding whether to try a technological device or application. This arithmetic is affective as well as intellectual. He reports how, as a teacher educator, he would have to develop pedagogies that support the student-teachers' competence in operating the graphic design software, so that they no longer find it too much trouble to use. Here theories of TPACK would benefit from explicit consideration of affect as one of the pedagogical factors that teachers must negotiate in their implementation of ICTs in pedagogy. Similarly, three of the four central factors of the UTAUT applied by Na-Allah and Nkambule to explore teachers' uptake of ICT training, namely 'performance expectancy, effort expectancy, [and] social influence', have strong affective components, which the primarily rationalist bent of the theory underestimates. The major finding of this study, which is failure of implementation because of a lack of consultation with teachers, shows how teachers' affective experience of being overlooked has very real empirical consequences, in their lack of motivation to use the ICTs provided in their classrooms.

Thinking about affect also helps understand how policy is power, exerted over bodies and affects as well as professional practice. The chapters by Dewa, Mlotshwa et al. and Na-Allah and Nkambule each in their different ways reflect on how individual teachers are embedded in standardising structures much larger than themselves and constrained by school, provincial and national power structures within the education system as a whole, on which they are largely dependent for policy, curriculum design and continued training and PD. Zembylas (2021) reminds us:

> The impact of standardizing processes as regulative technologies in schools is felt at the level of students, teachers, and school leaders, who are asked to regulate their performance in their everyday lives. The efficacy of standards as modes of governance, then, inevitably involves affective experiences and affective sense-making. (p. 2)

As discussed, where structures misframe and obscure real inequalities and inefficiencies, this will have profound emotional consequences for teachers and teacher educators. Participants in both Dewa's study (ch. 11) and Makonye's (ch. 9), for example, speak of the pressure of the forward momentum brought by ICT in the classroom, the relentless pace of market-driven development narratives, which causes them to be fearful of putting in the effort required to learn about available ICTs which will so soon be obsolete. This fear is exacerbated by the absence of professional learning opportunities or support.

Attention to affect thus reveals that this developmental narrative actually has a contradictory double affective loading. Visible in much technophilic discourse is the status of digital technology as a marker of modernity, development and success in global narratives of class, race and power. Digital devices such as iPhones therefore function not just as use objects but as objects of desire, and arguably ICTs in the educational context have similar functions. They can feature in policy statements, university branding and promotion motivations less as genuinely pedagogical interventions than as markers of the ‘right’ kind of modernity. Information and communication technology devices and competences can also feature in this aspirational way in individual teachers’ sense of themselves as professionals. Terms such as ‘21st-century skills’ and ‘modern teaching methods’, which create their meaning by celebrating ‘new’ over ‘old’ for no other reason than newness itself, implicitly rest on the developmental narratives of scientific rationalism that underpinned industrial expansion and colonisation. The affective weight carried by these neocolonial discourses, and by digital devices as objects of desire and investment, thus continues to shape South African society and inscribe on South African bodies their status as *other* and *lacking*. At the same time, the consequences of these developmental narratives are experienced in very real material ways, when social injustice is exacerbated, and emotionally and in the body, in the strain teachers feel of continually retraining yet never knowing enough.

The final moment of affective intensity I will discuss, however, is more hopeful. Phakathi and Moll, in Chapter 6, cite Battro’s theory of ‘the click option’ (2004:79), which posits that ‘global impact of digital technologies on human society, and particularly on education, is related to […] the ability to decide to produce a simple change of state in a system’. The very ubiquity of digital technology in our lives has dulled the sense of wonder that the first users of PCs and then of the Internet must have felt, as new horizons of information, textual creation and publication, communication, community and action opened before them. All it takes is the single click of a mouse. The potentialities brought into education by digital technologies, despite the complex political, economic, epistemological and ethical struggles they are embedded in, remain the inspiration and motivation of the study of ICTs in education.

Conclusion: Where to from here?

Bringing together rich reflections on how digital technology has changed and continues to transform teaching and teacher education in South Africa, the chapters in this volume speak in a range of voices about how best to integrate ICTs into education. It can often feel that the real reason why teachers must integrate ICTs into their teaching is 'because it's there', and there is a measure of truth to this, in some of the crasser versions of the technophilic discourse. However, as Nichols and LeBlanc (2020) emphasise, globally societies are becoming 'platformed societies', where 'platformisation' refers to the simultaneous consolidation of Internet resources into exchanges hosted on a small group of sites (such as Amazon, Apple, Facebook, Google, Microsoft) and the:

> [*S*]pread of mobile media into more facets of life [...] where platforms are not only a feature of everyday life but also a core part of our informal interactions, professional routines, and civic institutions. (p. 105)

South Africa is no exception. One consequence of this platformisation is that, as public culture theorists have argued, a new space is opening (Appadurai & Breckenridge 1995):

> [*B*]etween domestic life and the nation-state—where different social groups (classes, ethnic groups, genders) constitute their identities by their experience of mass-culture mediated forms in relation to the practices of everyday life. (pp. 4–5)

With the expansion of mobile phones even into the most rural areas, this space increasingly happens in digitally networked forms, in the 'networked publics' in which young people are active (ed. Itō 2010):

> The growing salience of networked publics in young people's daily lives is part of important changes in what constitutes the relevant social groups and publics that structure young people's learning and identity. (p. 19)

The chapters in this book focus largely on formal learning in classroom spaces, whether brick-and-mortar or digital. The next step will be to carry forward their insights into exploring how informal learning, in digitally networked publics, will intersect with and reshape South African education and offer new 'critical hope' (eds. Bozalek et al. 2014) for transformation.

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Chapter 1

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This book addresses theoretical, pedagogical, linguistic, curricular, and cultural dimensions linked to the essential practicalities of integrating educational technologies in the classroom in various forms and educational contexts. The chapters in the book address the critical question: 'How can the use of digital technology transform teaching and learning in general and teacher education in particular?' *Innovations in online teaching and learning: Case studies of South African teacher educators during COVID-19 era* examines the issue from a variety of stakeholder perspectives, including teacher educators, teachers, and students, as well as curricular content domains such as mathematics, engineering graphics and design, language, and chemistry, as well as assessment. A comprehensive understanding of a range of factors linked to knowledge to be acquired, student needs, and a broader consideration of specific elements related to inclusivity, social justice, and equity imperatives within the higher education landscape across several local, national, and global contexts is necessary to transform teaching and learning using digital technology. The key argument presented in this scholarly book concerns decision-making, uptake and resourcing elements related to pedagogical innovations employed in teaching practice.

Prof. Willy Mwakapenda, Department of Mathematics, Science and Business Education, Faculty of Humanities, Tshwane University of Technology, Pretoria, South Africa

A flood of journal articles and scholarly books has been written about the effects of COVID-19 on education, learning, and the use of digital technologies (ICTs) and the Internet of Things (IoT) to facilitate instruction. This book is among the few that provide a broader sense of the mayhem that besieged the emergence of emergency remote teaching (ERT). In this book, you will find an accurate synthesis of chapters written by authors of diverse backgrounds and expertise, all focusing on one theme and a summary of the pros and cons of digital technologies and pedagogy for e-learning and instruction.

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