AFRICAN PERSPECTIVES OF RESEARCH IN TEACHING AND LEARNING
ISSN PRINT: 2521-0262
ISSN ONLINE: 2662-012X

The Fourth Industrial Revolution: Teachers' Views on Integrating Digital Technologies As a 21-Century Teaching Strategy

Oscar Koopman
Stellenbosch University
Corresponding author: okoopman@sun.ac.za

ABSTRACT

Teachers in South Africa are faced with the colossal task of having to prepare learners for the Fourth Industrial Revolution (commonly referred to as 4IR). This undertaking entails aligning their teaching practices with the new demands and aspirations of 4IR goals and standards. Impelled by these new 4IR requirements, this paper asks two key questions: (i) How do selected Physical Science teachers understand the 4IR and their need to prepare learners adequately for 21-century learning? (ii) What are their views on integrating technological applications into their lessons to develop the 4IR skills the learners need in order to take advantage of the products of the 4IR? Theoretically, the paper draws on the Unified Theory of Acceptance and Use of Technology (UTAUT) model. The UTAUT model were deployed to report and discuss the teachers' views about integrating technology into their lessons. Methodologically, the paper adopted a Husserlian phenomenological approach to explicate data elicited from 12 purposively selected experienced Physical Science teachers. One-on-one, face-to-face semi-structured interviews and field notes were the main sources of data. The findings show that the teachers' understanding of 4IR is very basic and counterfactual. However, their views about integrating technology into their science lessons were directly shaped by their perception of the usefulness (PU) and effort expectancy (EE) associated with the use of technology. These aspects (PU and EE) affected their behavioural intentions, which in turn influenced their attitude towards the shift to 4IR teaching. The findings have implications for the professional development of experienced in-service teachers to effectively integrate digital technologies into their lessons to equip learners with the 4IR skills to take advantage of the products of the 4IR.

Keywords: Fourth Industrial Revolution; technology; teachers; physical science; phenomenology; South Africa

RATIONALE AND SIGNIFICANCE OF THIS STUDY

COVID-19 has raised key questions about the accelerated shift to 4IR skills and the teachers' integration of technological tools such as AI applications, social media platforms and various other web-based learning management systems into their science lessons (Koopman, Van Wyk and Koopman, 2020; Koopman and Koopman, 2021). This colossal demand placed on the shoulders of teachers raises the following questions: (i) Do South African science teachers understand what the shift to 4IR entail, and (ii) Were they sufficiently prepared to equip their learners with 21st-century 4IR skills? If the COVID-19 pandemic encouraged teachers to shift their pedagogies from technology-teacher interaction to technology-led and technology-driven teaching, how will the shift to 4IR affect science teaching? One of the main lessons learned from this pandemic is that teachers will be the key

drivers of new innovations and implementers of the 4IR tools in their classrooms. Therefore, there is a need to investigate more deeply how *experienced* physical science teachers view this shift from traditional teaching approaches to technology-led teaching and its effect on their practices moving towards 4IR. More specifically, what are their perceptions on integrating technological applications into their lessons to develop the much needed 4IR skills their learners will need to take advantage of the products of the 4IR?

Although many studies report on the potential benefits and opportunities that 4IR could offer, particularly the thickened connections between economic growth and development (South African Commission on the Fourth Industrial Revolution Report, 2020; Jandrick and Peters, 2018; Kelly, 2019), the COVID-19 pandemic gave us a glimpse of who will be driving economic development, create new opportunities for the disadvantaged, and soon become the main driver to solve problems in all sectors. We also witnessed how governments across the world (including South Africa) used web-based technological software for contact tracing of infected individuals and how researchers in the medical sector relied on e-technology such as AI to develop a vaccine to curb the spread of the virus. These new applications of online web-based technologies have also given rise to the development of powerfully advanced artificial intelligence applications, such as Chat GPT and various other AI tools and robotics that could be employed in the future and what the future job market might look like for various professions, specifically for teachers. Peters and Jandric (2019) had already predicted how new advances in AI might change the future job markets for teachers and academics due to continual new technological breakthroughs in the 4IR. This raises the question, what is the 4IR all about?

Klaus Schwab (2016) one the architects of the 4IR, already seven years ago predicted how the 4IR will be an age of unprecedented change with the emergence of automation, AI, 3D printing, digital computing and robotics. Peters, Jandric and Hayes (2021) report on the far-reaching impact of AI and automation, and how this affects (and will continue to affect) almost every aspect of humanity ranging from culture and economics to lifestyle and teaching and learning in schools and universities. It is argued that these phenomena will be built on the advancement of algorithms to expand the internet of things (IoT), which will eventually form a core infrastructural element of the 4IR. The algorithmic IoT is a technologically advanced system that consists of a range of smart and connected sensors where everything and anything can be interconnected through a communication medium (Pal, Hitchens, Rabehaja and Mukhopadhyay, 2020). According to these authors in 2022 as many as 28.5 billion devices such as smart phones, tablets, intelligent circuits, sensors, actuators, and many others is connected to the internet. This means that for every individual 2.3 mobile items are connected to the internet. This signifies the immeasurable pool of data generated from these devices that are interconnected to the various social media platforms, to realize some of the goals of the 4IR.

The South African Presidential Commission on the Fourth Industrial Revolution (PCFIR) (2020) offers an amended description of the 4IR as “an era where people are using smart, connected and converged cyber, physical and biological systems and smart business models to define and reshape the social, economic and political spheres” (p. 20). Linking Schwab’s notion of 4IR to the PCFIR’s description of 4IR gives us a broad perspective of the new world of technological revolutions and innovations that awaits teachers (and many other professions). Thus, preparing teachers for this new technological revolution is long overdue and requires teacher educators to have a good understanding of what this

epoch is all about so that they can develop a new vision for teaching and learning. In other words, in 21st-century teaching it is imperative to acknowledge this vision of 4IR by promoting: (i) critical thinking and problem-solving skills; (ii) collaboration across networks (Krueger, 2018); (iii) agility and adaptability (Peters, 2017); and (iv) entrepreneurialism (Peters, 2017). These are "high-level learning behaviours and skills" that depend on a solid grounding in online web-based technological tools (Wagner, 2010).

With the above understanding of 4IR and 21st-century teaching in mind, this article that adopted a phenomenological approach, asks two questions: (i) How do selected Physical Science teachers understand the 4IR and their need to prepare learners adequately for 21st-century learning? (ii) What are their views on integrating technological applications into their lessons to equip learners with the 4IR skills to take advantage of the products of the 4IR? The answers to these questions will inform and expand our understanding of possible challenges associated with the adoption of teaching approaches to prepare learners adequately for the 4IR. This will also shed some light on issues related to teachers adapting to the demands of 4IR by accepting web-based technology-led learning spaces in their teaching. The main reason for choosing Physical Science teachers is because their subject is viewed as the gateway to preparing learners for careers such as, engineering, computer science, mechatronics, robotics and coding, amongst many others. Since these careers will form the backbone of future technological developments and advancements, such as artificial intelligence, automation, machine learning and robotics, it is important to investigate the teachers' perceptions of 4IR and how they would integrate digital technology into their lessons. Currently, there is little information in the literature on *experienced* Physical Science teachers' understanding of 4IR. This significant research gap, particularly in the literature on phenomenological studies that investigate *experienced* Physical Science teachers' mental dispositions and intentions regarding the integration of technology as a 21st-century teaching strategy, prompted me to embark on this study that are important in adding value to the existing body of research on teaching and learning as we continue to move towards 4IR.

LITERATURE REVIEW

Waight and Abd-El-Khalick (2012) explain how science teaching has been revolutionised over the last few decades, advancing from the use of pencils and the chalkboard to laboratory equipment, interactive media, and computer hardware and software, including microcomputer laboratories, computer-based simulations and microworlds. More recently, we have seen how science teaching has expanded from pencils and chalkboards to the use of cell phones and iPads with their more advanced social media applications such as Facebook, WhatsApp, Blogs, Wikis and sophisticated Learning Management Systems such as Moodle, Blackboard, iKamva, amongst many others (Koopman, 2020) and AI tools such as Chat GPT. These tools refer to a process of socialization that encourages user-generated exchange of information and ideas as well as the inflow and outflow of knowledge to accelerate innovation (as in AI tools such as Chat GPT). Beastly and Peters (2013) a decade ago had the following to say about these social media tools: "these platforms become the basis for social (co-) production where individuals and communities share, co-produce and co-create content, code and new e-infrastructures and portals" (p.4). The question that begs here is "how effective are these and many other technological tools to promote quality science teaching?

Nxumalo-Dlamini and Gaigher (2019) report on the effectiveness of computer-based simulations (CBS) in the

teaching of electrolysis. Their study links their positive findings to the positive attitudes of science teachers towards CBS and how this rubbed off on their learners. Studies conducted by Ahmed, Almunium and Almabhouh (2016), Ma and Wang (2017) and Koopman *et al.* (2020) report on the tremendous benefits of mobile technologies for learners. Ma and Wang (2017) address how mobile technology (i) provide visual images of objects and scientific processes, (ii) offers greater flexibility for learning, and (iii) encourages greater interactive collaborations across networks both inside and outside the classroom. Koopman, van Wyk and Koopman (2020), who investigated Physical Science teachers' use of social media platforms, reports that YouTube was particularly popular. In agreement with Koopman *et al*. (2020), Bohloko, Makatja, George and Mokuku (2019) explored the use of YouTube as a teaching tool in the Chemistry classroom. They found that YouTube significantly enhanced not only learners' understanding of the periodic table, but also their performance.

Thus, the success of e-technology-enhanced science teaching, Lin, Tang, Shen, Liang, Tang *et al*. (2020) note, depends on the design of its use. Successful integration of technology in the classroom depends strongly on support for and training of teachers. Studies have shown that if teachers believe that mobile technologies do not assist them or their learners in the science classroom, they might use or integrate the technology poorly or ineffectively (Koopman, et al., 2020). Teachers' attitudes towards technology have been linked to aspects such as its perceived usefulness and their confidence as well as to fear and anxiety due to a lack of support and training (Teo, Lee and Chai, 2008). Other challenges external to technology acceptance include the limited technological skills of teachers; some teachers lack confidence and are reluctant to move beyond traditional pedagogies; poor internet and WiFi connectivity; the loss of what they feel is valuable teaching time; and the preference among some students for traditional approaches (Johnson, Kimball, Melendez et al., 2009; Zhoa, Wang, Li, Zhou and Li, 2021).

THEORETICAL FRAMEWORK

To understand the teachers' views on the integration of technology into their classroom practice, the paper draws on the Unified Theory of Acceptance and Use of Technology (UTAUT) (Dwivedi, Rana, Jeyaraj, Clement & Williams 2017) that is integrated with Heidegger's notion of *Dasein* to help understands the teachers' experiences. The UTAUT framework is adapted from Venkatesh, Morris, Davis and Davis' (2003) who modified Davis, Bagozzi, and Warshaw's (1989) Technology Acceptance Model (TAM). These models have been applied to ascertain end users' acceptance of technology across various organizations, including education. These models have its origin in Ajzen and Fishbein's (1980) Theory of Reasoned Action (TRA), which is not going to be discussed further in this paper due to space constraints.

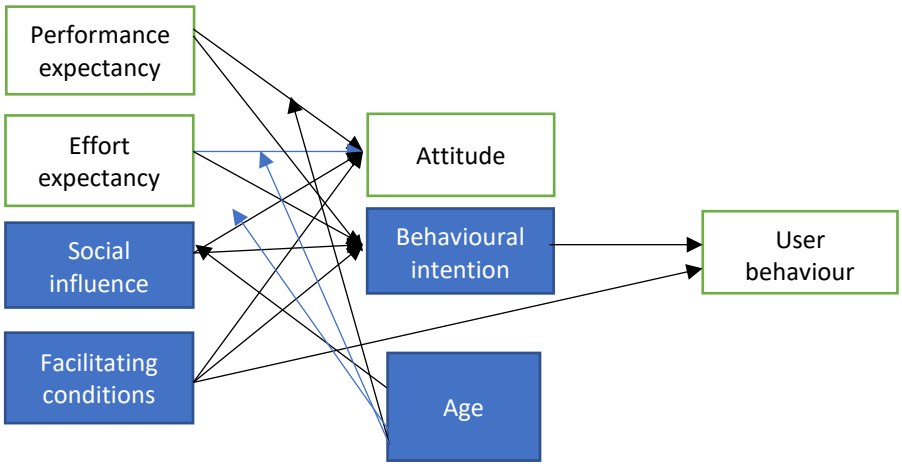
The crux of the UTAUT model is to explain whether or not a person (in this study teachers) will accept or reject new technologies, particularly artificial intelligence applications, robotics, online social media platforms and so forth. Teacher acceptance of technology, these authors argue, lies in its Perceived Usefulness (PU) and Perceived Ease of use (PE). Dwivedi et al. (2017) view attitude as "a mediator between Performance Expectancy (PE) and Behavioural Intention (BI), and between Effort Expectancy (EE) and Behavioural Intention". In other words, attitude and behavioural intention form the basis of user motivation to adopt new ideas linked with technology. Figure 1.1 below illustrates the working of the UTAUT

As illustrated in Figure 1 below, EE is the fusing of expectancy and use of technological tools - such as smart phones, tablets, e-books, etc. Social influence is the degree to which important others (such as curriculum planners and policymakers) believe that the teachers should adopt and implement 4IR skills in their classroom, while facilitating conditions (FC) are the support and availability of resources such as e- and-m-learning gadgets that the teachers might need to plan lessons effectively and efficiently with 4IR skills in mind (Dwivedi et al., 2017). Attitude refers to the teachers' positive and negative feelings towards technology, while the behavioural intention (BI) is determined by the strength of the teachers' intention to use the technological tools. Since the teachers in this study are all *experienced* educators, age could have a direct impact on their attitude and BI regarding the demands of technology on their teaching. In other words, the views of seasoned teachers might be different from those of younger teachers who grew up with the technology and use it daily.

METHODOLOGY

This study adopted a Husserlian phenomenological approach as an appropriate and effective method to investigate the teachers' own understanding of 4IR as well as their perceptions about integrating digital technology into their teaching on the basis of their personal stories. This is because Husserl's phenomenology gives the researcher direct access to the finer details of the teachers' epistemic consciousness that shapes their action and behaviour (attitudes) as they recount their personal views about the 'what' and the 'why'. According to Husserl (1967), phenomenologists do not "make assertions" about what they do not see (p. 9), but aim to gain insight into the teachers' subconsciously held ideas about 4IR and the impact of PU and EE on the teachers behaviour, and how PU and EE are linked to the social influences as well as the facilitating conditions that motivate (or not) the teachers to integrate digital technology in their lessons.

Figure 1: The Unified Theory of Acceptance of Technology (UTAUT) adapted from Venkatesh et al. (2003)



To capture the voices of the teachers on these issues, the researcher adopted two forms of data collection: (i) a semi-structured, face-to-face, one-on-one phenomenologically oriented interview with each participant; and (ii) field notes. Each of the three parts of the interview was audio-recorded and transcribed. Part one focused on the context such as the details of their qualifications, years of experience, background and facilities of the school, and so forth. The questions on 'background' and 'facilities' were intended to ascertain whether the schools were technologically

rich spaces – does the school have a computer laboratory, Wi-Fi connectivity, mobile devices and gadgets? Part two of the interview focused on the teachers' understanding of the 4IR. At this stage the focus was on questions such as 'What do you think 4IR is about and how it will affect the way you teach Physical Science?' Part 3 of the interview was intended to deepen the researcher's understanding of their worlds by asking them more personal and probing questions – focusing on their mindsets to understand how they feel about integrating technology as a 21st-century teaching strategy. Here the focus is on asking the participant to sink into their subjective experience and describe it and to elaborate on that description with the help of the researcher. More specifically, it was on ascertaining their main concerns, challenges and fears (if any) about technology – particularly on whether they received training, what skills they have, information on whether or not their classrooms are technologically well equipped, whether learners have smart phones, and so forth.

Field notes were also taken during and after each interview. The researcher recorded all paralinguistic activities displayed during each interview, such as the length of pauses between responses, facial expressions, attitude and behaviour, tone and pitch of voice. The interview data were augmented with this information to provide a rich description of each research participant's experiences.

4.1 The Research Participants

A total of 12 Physical Science teachers were purposively selected to participate in the study. The researcher 'handpicked' the participants, taking an array of factors into consideration, such as the province in which they teach, features such as race, qualifications, age, gender, region, teaching experience, and the quintile index rating of the school.

Table 1: Overview of the biographical details of the research participants

Pseudonym	Province	Age	Race	Gender	Years of experience	Qualifications	Major subjects	Quintile index rating of the school
A	WC	55	C	M	28	BSc	Chem Math	3
B	WC	62	C	M	38	BSc	Physics Math	3
C	WC	45	C	F	16	BEd (Sc)	Phy Sc Math	5
D	WC	48	C	M	22	BSc, PGCE	Chem Math	5
E	WC	45	C	F	15	BEd (Sc)	Phy Sc	4
F	WC	53	C	F	26	BEd (Sc)	Phy Sc	4
H	WC	56	C	M	34	BEd (Sc), BEd (Hons)	Phy Sc Life Sc	3
I	G	38	A	M	15	BEd (SC)	Phy Sc	2
J	G	53	W	F	15	BEd (Sc)	Phy Sc	5
K	G	55	C	F	24	BSc (Eng)	Chem	5
L	G	48	A	M	16	BEd (Sc)	Phy Sc	3
M	G	52	C	M	21	BEd (Sc)	Phy Sc	2

As this study forms part of a much broader research project that investigates the lived experiences of *experienced* Physical Science teachers, financial constraints meant that the researcher could select teachers for this study only from

Gauteng and the Western Cape, the two wealthiest provinces in the country (highest income per capita). After the data were analysed, two colleagues – one an experienced phenomenologist and the other a technology education specialist – were invited to work through the data to verify the accuracy of the interpretations. This led to a further refinement of the data after all queries and concerns were addressed.

4.2 DATA EXPLICATION FRAMEWORK

Each transcript provided the experiential accounts and portraits narrated from the point of view of the teachers' experiences. Following Husserlian phenomenology, the researcher rigorously segmented the data and worked through each transcript following a step-by-step approach in breaking down the raw and unprocessed data word-by-word and line-by-line. From these words, phrases, lines and statements he developed units of meaning underlying the subjective intuitions or consciousness of the teachers, guided by the use of high-frequency words, phrases and sentences with similar meanings. These words, phrases and sentences are sorted according to units of meaning and arranged for clarity, keeping intact the relations among these constituents relative to the structure of the whole experience. In the phenomenological tradition the UoM, provide a rich descriptive and interpretive narrative of the structure of the experience of the phenomenon. As such an analysis in the phenomenological tradition means that the researcher must use mostly the direct words of each participant as they appear in the respective transcripts.

To move beyond the Husserlian tradition of analysis, the researcher adopted Heidegger's (1967) ontological philosophical approach, which allowed him to present an interpretive account of each teacher's narrative. In short, this requires the researcher, like a diver to look beneath the surface of the ocean, scrutinising each word, phrase, sentence and paragraph in the interview transcripts meticulously in order to get an overall sense of the nature and essence of each participant's understanding of the 4IR as well as their teaching approaches. The interview as a whole provided a context for the emergence of specific meanings and events. From this the researcher deduced the teachers' understanding of 4IR and how they would/might approach technology.

ETHICAL CONSIDERATIONS

Trustworthiness of the Data Construction Process and Presentation of the Findings

After, ethical clearance were received from the various institutions the researcher conducted the one-on-one semi-structured interviews. After completing the data construction process, all recorded interviews were transcribed to text. Each transcript of the various data sets obtained from the interview were emailed to the respective participants to verify whether the transcriptions were a true reflection of the interviews. By so doing, each research participant confirmed the accuracy of their views. Therefore, whenever phenomenologists report on a participant's perceptions and understanding of a phenomenon (in this case 4IR), they sketch their subjective reality fairly accurately. To ensure research rigor, the researcher adopted Husserl's (1967, p. xx) mantra of "bracketing the self" during every step of the data-construction process. "Bracketing" oneself from the research participant allows the researcher to go "back to the things themselves". Thus, the researcher allowed every participant's dialogue during the interview to flow in an uncontaminated manner, making him/her the absolute source of the data revealing each participant's idiosyncratic history and make-up with situation, place, people and ideas (Grumet, 2015). Thus, the trustworthiness of a phenomenological

approach rests in the researcher's ability to allow each research participants inner voices and stories be narrated in their own words, to answer the main research questions after adopting an appropriate methodology.Thus, to ensure credibility and validity of the data, the researcher ensured fidelity to the phenomenon, consistency in the process of analysis, and reproducibility and reliability of the data analysis as a whole.

FINDINGS
RESEARCH QUESTION ONE

6.1.1 VIEWS ABOUT 4IR OF THE TEACHERS IN THE WESTERN CAPE

The following comment by teacher A summarises the teachers' views and understanding of the 4IR and how it relates to science teaching:

> *Well, the 4IR is about allowing learners to use their cell phones. My role now is to teach by letting them search for the information on the cell phone using Google or YouTube. … I don't know how to do this, but this is what it is. Then they also want us to use Facebook and WhatsApp, but not every learner in my class has a cell phone. So some will get the messages and information on WhatsApp while others not …*

Teacher B, who has 38 years' experience and is also the deputy principal, described the 4IR as a space

> *where the use of computers allows learners to surf the internet on Google for information. So yes, it's all about technology which is why the Department now wants us to use our cell phones in the classroom, …but I'm not sure where I will find the time for this because I must finish my syllabus…*

Teachers C and D, like A, who teach in the same school described the 4IR as an era of the cell phone. C said

> *we are expected to guide the learners on how to use their cell phone as a tool with which they can search for information and allow them to form WhatsApp groups so that they help one another… the problem is, most of the time I am forced to use my own data if I want to share information so I'm not really happy with this.*

D added,

> *we must now be connected to the Wi-Fi at all times so that our learners can develop the skills to use their smartphones and other devices as a way of learning new things and ideas in the science classroom. So the 4IR demands that we use Facebook, WhatsApp and so on; I'm not so sure if it will work because not every learner has a cell phone…"*

Teacher H referred to the 4IR as "*something that we are encouraged to focus on for a long time now. First, we had to learn how to use these programs on the computer, … but now it's all about using Facebook and WhatsApp in our lessons*".

6.1.2 VIEWS OF THE TEACHERS IN GAUTENG

Teachers I and L (both from Gauteng) pointed out that the 4IR is not

much different from what they are already doing in the classroom. Teacher I commented: *"Well, I know how to use the internet, I'm using WhatsApp and are always in contact with my learners"*. Teacher L said, *"… but we have been doing this all the time, using Facebook … and all my notes are electronic, this is what I like about the 4IR, I don't have to write out notes on the board all the time because my notes are typed out. This saves me a lot of time".*

Teachers J and K, both female who teach in the same school and whose classrooms are right next to each other, held similar views to those of I and L about what the 4IR entails. To them it was all about incorporating technology and cell phones into their teaching. J described 4IR as the use of *smartboards, computers, the internet and social media platforms in their teaching,* and K similarly described it as a new era where teachers and learners are in constant contact with each other. She said "*cell phones are now taking over our teaching. When I download a YouTube video from the internet I play it for them in the classroom and if they want me to share it with them on WhatsApp, I can do it".*

Teacher M said smilingly, "*well this is the era of the computer, the cell phone and any technological device. Although most people use the cell phone for social media, I guess we must do the same by using social media in the classroom…"*

These findings summarise the teachers' understanding of the 4IR in relation to their teaching of science.

6.1.3 RESEARCH QUESTION TWO

Teachers' views in the Western Cape province

Six of the seven teachers who teach in the Western Cape expressed their frustration at the idea of integrating digital technologies into 21st-century teaching. Teacher H's response summarises the practical and social challenges they face:

> *These politicians, and policy makers are clearly out of touch with what is happening in our schools. I agree, it is a wonderful idea but how do they expect us to drive their agenda. … I'm sorry [deep frown on face, and harsh tone] but this will never happen in our school. It takes me two periods just to hand out the tablets. … This takes a lot of time. Then it takes half the period just to get to their attention as they do who knows what with the devices. They don't listen because they are more interested in the thing than what I have to say…*

Similarly, teachers F and B echo their concerns with the skills required to integrate digital technology effectively into their classroom practice. They stated that they did not receive adequate training by the Department on how to use technology, nor did they receive training when they studied to become teachers. For example, teacher B said *"I studied in the late 1970s; back then there were no such thing as a computer. I know how to use a cell phone but how to use it in the classroom is a different story".* Teacher F mentioned that she does not feel comfortable with using these smart devices like cell phones, iPads and tablets. *"Luckily, my son, who is now in his twenties help me, but that is about it because he can't help me with using it in the classroom".*

Teachers D and E, who teach in the same school (Quintile 5 technical school),

expressed feelings of frustration, helplessness and disappointment with school management, which fails in its task to provide stable internet reception. Teacher D commented that *"one day it works, the next moment it's off. It looks like they don't care about our complaints, because I have given up on this, ... I also just don't care"*. Teacher E added that *"most of the time we [some teachers] have to use our own cell phones as a hotspot ..., then I have to make up for the lost time ... with afternoon classes"*. Teacher B, who teaches in a historically disadvantaged area, expressed the following concern: *"Well, if they are going to give us training, that might help, but I can tell you now that these subject advisors who is supposed to help and guide us are doing a lousy job…"*. He further added *"One [subject advisor] came here one day and said to me I like your notes, ... I later discovered that they go to other schools and give it to teachers there and claim it to be their own work"*. Teacher F, with 26 years of experience said: *"I don't even know what they expect from us [frowning face and lifting up her hands]. They must first come show me how the content can be linked to smartphones…"*.

Teachers' views in Gauteng

The findings showed that the Department of Basic Education in Gauteng provides regular training for teachers. These training sessions take place during the week, over weekends and during school holidays. When asked what their views are about integrating digital technologies into their lessons, teacher I said, *"I'm already using Facebook in my lessons. We also have a WhatsApp group on which we post question papers or questions"*. He continued, *"On these WhatsApp groups my learners know what they are expected to do. They can post solutions; they can exchange ideas and they help each other"*. Teacher M commented: *"I must say, this is a very good idea because when our learners go to university than they are well prepared on how to use technology ... I can connect with my students and guide them. It's just that the Wi-Fi must work…"*

Teachers J and K stated that although they are not technologically adept, they have the support of management and their learners in the classroom. The following comment substantiates this claim by teacher J: *"You know my learners are very helpful. When we prepare our lessons, we know our learners know we are not so smart as they are when we must use iPads and cell phones. So what I do is I will ask in my lessons help from my learners to show me how to upload notes or a nice video onto WhatsApp"*. J added *"They [learners] are eager to help, so as much as they learn from us, we learn from them"*.

Teacher K added: *"When I don't know how to do something I ask my colleague who is next door to me ... That's the only way to survive as technology changes all the time and yes, we must also change"*.

What stands out in Gauteng province is the amount of time devoted to professional development on how to use technology in the classroom. Teacher J supported this statement as follows: *"We really like the workshops on technology offered by the Department. We go for training regularly. Sometimes it's offered by officials and at other times by teachers, and it really helps"*.

6.4 DISCUSSION

6.4.1 RESEARCH QUESTION ONE

All the teachers in this study (in both provinces) provided a very basic description of 4IR as a technologically enhanced teaching and learning space in which they have to integrate cell phones into their lessons. These descriptions are subjective and counterfactual with respect to what 4IR is about according to the Presidential Commission on 4IR Report.

Counterfactual thinking, Marwala (2021) points out, is essentially a process of comparing what one knows with what is happening. Such understanding or perception he argues, has a direct bearing on the pedagogical decision a teacher makes. The Curriculum and Assessment Policy Statement for Physical Science does not make any reference to 4IR (DoBE, 2011), particularly regarding the potential power of AI and robotics in the science classroom. Furthermore, The Presidential Commission on 4IR Report (2020) shows that 4IR is still in its embryonic stage as no roll out plan about the goals and objectives has yet been provided. This report and the fact that the CAPS is still mainly situated in 3IR, where the focus is mainly on the use of the internet, the use of mobile technological devices and the use of innovative and creative pedagogies explains why the teachers in this study have a counterfactual understanding of 4IR.

Peters et al. (2021) describe 4IR as an era characterised as a bio-digital age where technological advances lead to the convergence of the concept of technoscience and its related nano-bio-info-cognitive models of our understanding of the world, but this understanding has not yet been conceptualised or contextualised in curriculum and policy documents in South Africa. This new paradigm of convergence in the sciences will potentially lead to more technological advances that will gradually be integrated with human behaviour and actions, leading to data-driven technologies such as artificial intelligence (AI).

6.4.2RESEARCH QUESTION TWO VIEWS OF THE TEACHERS IN THE WESTERN CAPE

The concerns and challenges of the teachers in the WC are mainly related to: (i) lack of skills on how to use/integrate digital technological tools into their lessons (Teacher F), (ii) a lack of training (Teachers B, F and C), (iii) a lack of support from management (Teachers C and H), (iv) the foreignness of gadgets (Teacher H), (v) loss of time (Teachers H and E), and (vi) helplessness and frustration because of the lack of training (Teachers E and F).

According to Dwivedi's (2017) UTAUT model, these findings indicate a negative PU which culminated in their reluctance to use or integrate technology into their lessons. The findings also reflect the teachers' subjective concerns that digital technology is not beneficial to them or their learners in achieving more effective lesson delivery. Teachers B, C, F and H acknowledged that it will require a lot of effort to fully grasp the effective use of digital tools. This means that their EE in developing the skills to effectively use technology directly shaped their continued reluctance to use it in their classrooms. Drawing on the UTAUT model, when teachers have a negative PU and EE, their mindsets towards the use of technology are directly affected. In the case of the teachers in the WC, their negative mindset about technology due to their low PU and EE is further exacerbated by the social influences (policies in place on integrating technology into their lessons) and facilitating conditions (poor resources in and outside the school). Their age is another contributing factor, as confirmed by teacher F, who pointed out her dependency on her son. All these aspects directly influenced the PU and EE, which negatively impacted on their attitudes and behavioural intentions that made them reluctant to integrate technology into their lessons. Ziegler (2007) reminds us that such challenges culminate in a reluctance to use the technology, which might in turn (as the findings suggest) develop into a fear of miseducating their learners.

VIEWS OF THE TEACHERS IN GAUTENG

The positive views of the teachers in Gauteng are one consequence of the regular

training provided by the Department of Basic Education. This is because regular training instilled in their minds a positive PU and EE (Dwevide *et al.* 2017). Evidence of this is evident when all the teachers pointed out in agreement that the use of digital technologies like Facebook, WhatsApp and YouTube are beneficial for their learners. This finding is in agreement with the findings of Teo *et al.* (2008), who report that teachers' positive mindset towards the integration of technology in their lessons, irrespective of age, encourages them to integrate digital technology as a 21st-century learning tool in their lessons. Thus, when the teachers have a positive disposition towards PU and EE because of continuous training, they mainly see the usefulness of technology in the science classroom. This (positive PU and EE) has a direct effect on the teacher's attitudes and behavioural intentions (Venkatesh et al., 2003), resulting in the use of digital technologies, irrespective of facilitating conditions, social conditions or age.

6.5 CONCLUSION AND RECOMMENDATIONS

Salient findings of this study are that the teachers' very basic description and understanding of the 4IR and the influence of PU and EE on science teachers' mindsets which directly influence their behaviour and attitude towards integrating technology into the science classroom. The teachers' basic misconstrued understanding of 4IR they have in their minds is also expressed in their pedagogical practices. Thus mental disposition, emerged from the findings, can also be described as their transcendental reference to the way they enliven 4IR in the classroom. This means the participants' intermingling with 4IR technologies in the classroom is a function of their perceptive-affective lived experience From this perspective the findings showed that a teacher's positive/negative mindset towards the use of technology can be linked to a teacher's belief about its PU as well as the EE, or put differently, a teacher's perceived ease of use (or difficulty) of technology.

Therefore, successful shifting towards the integration of digital technologies lie in continued training. An implication of this study is that there is a need to provide science teachers with effective professional development training. Additionally, although the findings of this small sample size study cannot be generalised, they offer district officials fresh insight into how to design and structure their professional development programmes for science teachers to prepare them for the 4IR. Therefore, preparing teachers for the 4IR and the integration of technology into their classroom practices is a critical 21st-century teaching strategy that will become increasingly essential for physical science teachers.

6.6 REFERENCES

Ajzen, I., & Fishbein, M.M. (1980). *Understanding attitudes and predicting social behaviour*. Eaglewood Cliffs: Prentice-Hall.

Ahmed, A, M., Almuniem, A., & Almaghouh, A. (2016). The current use of Web 2.0 tools in the university teaching from the perspective of faculty members at the college of education. *International Journal of Instruction* 9(1), 179-194.

Bohloko, M., Makatjana, T., George, M., & Mokuku, T. (2019). Assessing the effectiveness in using YouTube videos in teaching the Chemistry of groups 1 and VII elements in high schools in Lesotho. *African Journal of Research in Mathematics, Science and Technology Education* 23(1), 75-85.

https://doi.org/10.1080/18117295.2019.1593610

Beastly, T., and Peters, M. (2013). The creative university: Creative social development and academic entrepreneurship. In M. Peters and T. Beastly (eds), *Re-imagining the creative university for the 21st century*. Rotterdam: Sense Publishers

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science* 35(8), 982–1003.https://doi.org/10.1287/mnsc.35.8.982

Department of Basic Education and Training. (2011). *Curriculum and Assessment Policy Statement for Physical Sciences.* Pretoria: Government Printers.

Dlamini, N.L., & Gaigher, E. (2019). Teachers' use of computer-based simulations in teaching electrolysis: A case study in Eswatini. *African Journal of Research in Mathematics Science and Technology Education, 23*(3), 320-331.

Dwivedi, Y.K., Rana, N.P., Jeyaraj, A., Clement, M., & Williams, M.D. (2017). Re-examining Unified Theory of Acceptance and Use of Technology: Towards a revised theoretical model. *Information System Frontiers* 21, 719-734.

Grumet, M. (2015). Existential and phenomenological foundations of autobiographical methods. In F. Pinar and W.M. Reynalds (Eds). *Understanding curriculum as phenomenological and deconstructed text.* New York: Educators International Press.

Heidegger, M. (1967). *Being and time* (J. Macquarrie & E. Robinson, Trans.). London: SCM Press.

Husserl, E. (1967). *The Paris lectures* (2nd Ed),(P. Koestenbaum, Trans). The Hague Netherlands: Marthinus Nijhoff Publishers.

Johnson, A., Kimball, R., Melendez, B., Myers, L., Rhea, K., & Travis, B. (2009). Breaking with tradition: Preparing faculty to teach in a student-centered or problem-solving environment. *Primus* 19(2), 146–160.https://doi.org/10.1080/10511970802409164

Koopman, O., Van Wyk, M., & Koopman, K.J. (2020). Science teachers' views on technology-based teaching. *International Journal of Learning Technologies, 13*(3), 25-46.

Koopman, O., & Koopman, K.J. (2021). Is this the end of indigenous knowledge? The impact of the neoliberal technological epoch on the decolonization of the university curriculum. *South African Journal of Higher Education, 35*(1), 127-142.

Kelly, R. (2019). *Constructing leadership 4.0: Swarm leadership and the fourth industrial revolution*. New York: Palgrave Macmillan.

Krueger, K. (2018). Back to the future: What the coming fourth industrial revolution means for education. *Advocacy*, 23-24.

Lin, F., Tang, D., Shen, W., Liang, Z., Tang, Y. & Tsai, C. (2020).

Exploring the relationship between perceived technology-assisted teacher support and technology-imbedded scientific inquiry: The mediation effect of hardness. *International Journal of Science Education, 42*(8), 1225-1252.

Ma, Q., & Wang, L. (2017). Community of practice: Building a mobile learning community in a higher education institution to promote effective teaching and learning. In S.C Kong, T. L. Yang & C. F Tse (eds). *Emerging practices in scholarship of learning and teaching in a digital age.* New York: Springer.

Marwala, T. (2021). *Rational machines and artificial intelligence*. London: Academic Press. Nxumalo

Pal, S., Hitchens, M., Rabehaja, T., & Mukhopadhyay, S. (2020). Security requirements for the internet of things: A systematic approach. Sensors, 20(20), 5897. https://www.mdpi.com/1424-8220/20/20/5897/pdf https://doi.org/10.3390/s20205897

Peters, M. (2017). Technological unemployment: Educating for the fourth industrial revolution. *Journal of Self-Governance and Management Economics* 5(1), 25-41.

Peters, M., & Jandric, P. (2019). Posthumanism, open ontologies and biodigital becoming: Response to Luciano Floridi's online manifesto. *Educational Philosophy and Theory, 51* (10), 971-980.

Peters, M., Jandric, P., & Hayes, S. (2021). Postdigital -biodigital: An emerging configuration. *Educational Philosophy and Theory*, 1-15. Commission on the Fourth Industrial Revolution (2021). *Summary report and recommendations on the Fourth Industrial Revolution*. Pretoria: Government Printers.

Schwab, K. (2016). *The fourth industrial revolution*. Geneva: World Economic Forum.

Schwab, K., & Davis, N. (2018). *Shaping the future of the fourth industrial revolution*. New York: Crown Publishing Group.

South African Report on the Presidential Commission on the Fourth Industrial Revolution. (2020). Summary report and recommendations. Pretoria: Government Printers

Teo, T., Lee, C.B., Tsai, C.S. (2008). Understanding pre-service teachers' computer attitudes: Applying and extending the Technology Acceptance Model. *Journal of Computer Assisted Learning, 24*(2), 128-142.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly* 27(3), 425–478.DOI: 10.2307/30036540

Wagner, T. (2010). *The global achievement gap: Why even our best schools don't even teach the new survival skills our children need – and what we don't do about it.* New York: Basic Books

Waight, N., & Abd-El-Khalick, F. (2012). Nature of technology: Implications for design, development and enactment of technological tools in school science classrooms.

International Journal of Science Education, 34(18), 2875 – 2905.

Ziegler, S. (2007). The (mis)education of Generation M. *Learning, Media and Technology Journal* 32(1), 69–81.

Zhoa, Y, Wang, N, Li, Y., Zhou, R., and Li, S. (2021). Do cultural differences affect users' e-learning adoption? A meta-analysis. *British Journal of Educational Technologies, 52*(1), 20-41.